TRANSACTIONS

OF THE

AMERICAN FISHERIES SOCIETY

1935

SIXTY-FIFTH ANNUAL MEETING

TULSA, OKLAHOMA

SEPTEMBER 9, 10 and 11, 1935

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OF THE

American Fisheries Society

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September 9, 10 and 11, 1935

Published Annually by the Society

Washington, D. C.

1935

Printed in the U. S. A.

THE AMERICAN FISHERIES SOCIETY

Organized 1870 **Incorporated 1910**

The Society was organized to promote the cause of fish culture; to gather and diffuse information of a scientific character; and to unite and encourage those interested in fish culture and fisheries problems.

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Protection and Legislation.............GUY AMSLER, Little Rock, Arkansas
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VICE-PRESIDENTS OF DIVISIONS

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Aquatic Biology and Physics.............A. S. HAZZARD, Ypsilanti, Mich.
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Angling.............S. B. LOCKE, Chicago, Illinois

***For street addresses see membership list.**

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Herbert C. Davis — San Francisco, Calif.
Fred J. Foster — Seattle, Wash.
Thaddeus Surber — St. Paul, Minn.
Fred Westerman — Lansing, Mich.

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W. J. K. Harkness — Toronto, Can.
John O. Snyder — Stanford University, Calif.
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Raymond J. Kenney	Boston, Mass.
M. D'Arcy Magee	Washington, D. C.
Grover C. Ladner	Philadelphia, Pa.
J. A. Rodd	Ottawa, Canada

PRESIDENTS' TERMS OF SERVICE AND PLACES OF MEETING

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift	1870-1872	New York, N. Y.
2.	William Clift	1872-1873	Albany, N. Y.
3.	William Clift	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt	1876-1877*	New York, N. Y.
7.	Robert B. Roosevelt	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt	1881-1882	New York, N. Y.
12.	George Shepard Page	1882-1883	New York, N. Y.
13.	James Benkard	1883-1884	New York, N. Y.
14.	Theodore Lyman	1884-1885	Washington, D. C.
15.	Marshall McDonald	1885-1886	Washington, D. C.
16.	W. M. Hudson	1886-1887	Chicago, Ill.
17.	William L. May	1887-1888	Washington, D. C.
18.	John Bissell	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall	1891-1892	Washington, D. C.
22.	Herschel Whitaker	1892-1893	New York, N. Y.
23.	Henry C. Ford	1893-1894	Chicago, Ill.
24.	William L. May	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington	1895-1896	New York, N. Y.
26.	Herschel Whitaker	1896-1897	New York, N. Y.
27.	William L. May	1897-1898	Detroit, Mich.
28.	George F. Peabody	1898-1899	Omaha, Nebr.
29.	John W. Titcomb	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant	1901-1902	Milwaukee, Wis.
32.	George M. Bowers	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark	1903-1904	Woods Hole, Mass.
34.	Henry T. Root	1904-1905	Atlantic City, N. J.

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

35. C. D. Joslyn	1905-1906	White Sulphur Springs, W.Va.
36. E. A. Birge	1906-1907	Grand Rapids, Mich.
37. Hugh M. Smith	1907-1908	Erie, Pa.
38. Tarleton H. Bean	1908-1909	Washington, D. C.
39. Seymour Bower	1909-1910	Toledo, Ohio
40. William E. Meehan	1910-1911	New York, N. Y.
41. S. F. Fullerton	1911-1912	St. Louis, Mo.
42. Charles H. Townsend	1912-1913	Denver, Colo.
43. Henry B. Ward	1913-1914	Boston, Mass.
44. Daniel B. Fearing	1914-1915	Washington, D. C.
45. Jacob Reighard	1915-1916	San Francisco, Calif.
46. George W. Field	1916-1917	New Orleans, La.
47. Henry O'Malley	1917-1918	St. Paul, Minn.
48. M. L. Alexander	1918-1919	New York, N. Y.
49. Carlos Avery	1919-1920	Louisville, Ky.
50. Nathan R. Buller	1920-1921	Ottawa, Canada
51. William E. Barber	1921-1922	Allentown, Pa.
52. Glen C. Leach	1922-1923	Madison, Wis.
53. George C. Embody	1923-1924	St. Louis, Mo.
54. Eben W. Cobb	1924-1925	Quebec, Canada
55. Charles O. Hayford	1925-1926	Denver, Colo.
56. John W. Titcomb	1926-1927	Mobile, Ala.
57. Emmeline Moore	1927-1928	Hartford, Conn.
58. C. F. Culler	1928-1929	Seattle, Wash.
59. David L. Belding	1929-1930	Minneapolis, Minn.
60. E. Lee LeCompte	1930-1931	Toronto, Canada
61. James A. Rodd	1931-1932	Hot Springs, Arkansas
62. H. S. Davis	1932-1933	Baltimore, Md.
63. Fred A. Westerman	1933-1934	Columbus, Ohio
64. E. L. Wickliff	1934-1935	Montreal, Canada
65. Frank T. Bell	1935-1936	Tulsa, Oklahoma

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PART I
BUSINESS SESSIONS

TRANSACTIONS

OF THE

65th Annual Meeting of the

AMERICAN FISHERIES SOCIETY

TULSA, OKLAHOMA

September 9, 10 and 11, 1935

E. L. WICKLIFF, *Presiding*

The 65th Annual Meeting of the American Fisheries Society convened at 10:00 A. M. on September 9, 1935, at the Hotel Mayo, Tulsa, Oklahoma, the President, E. L. Wickliff, of Columbus, Ohio, presiding.

The meetings were held in cooperation with the International Association of Game, Fish and Conservation Commissioners.

The registered attendance of members, delegates, and guests was as follows:

REGISTERED ATTENDANCE

Aitken, W. W., Des Moines, Iowa
Aitken, Mrs. W. W., Des Moines, Iowa
Aldrich, A. D., Tulsa, Okla.
Aldrich, Mrs. A. D., Tulsa, Okla.
Allen, C. H., Tulsa, Okla.
Atherton, Giles, El Dorado, Kan.
Axe, R. A., Bartlesville, Okla.

Bagby, Dr. E. L., Enid, Okla.
Bailey, Geo. W., Oklahoma City, Okla.
Bailliere, F. L., Stoutland, Mo.
Balch, Ray V., Tulsa, Okla.
Barker, Elliott S., Santa Fe, New Mexico
Barnett, Jessie, Topeka, Kan.
Bell, Frank T., Washington, D. C.
Bode, I. T., Des Moines, Iowa
Bode, Mrs. I. T., Des Moines, Iowa
Boone, M. H., Oklahoma City, Okla.
Bottom, W. G., Tulsa, Okla.
Boyd, Walter, Claremore, Okla.
Brandner, Henry, Tulsa, Okla.
Brennan, B. M., Seattle, Wash.
Brill, C. J., Oklahoma City, Okla.
Brown, Dell, Mammoth Springs, Ark.
Brown, James, Montpelier, Vt.
Brown, M. W., Sacramento, Calif.
Burleson, Clyde, Cherokee, Okla.

Campbell, C. Watt, Tulsa, Okla.
Carper, H. O., Tulsa, Okla.
Carson, E. T., Shawnee, Okla.
Carson, Mrs. E. T., Shawnee, Okla.
Casey, W. H., Ponca City, Okla.
Catlett, John G., Tulsa, Okla.
Catlett, Mrs. John G., Tulsa, Okla.
Chalk, J. D., Raleigh, N. C.
Chandler, Bob, Muskogee, Okla.
Chute, W. H., Chicago, Ill.
Chute, Mrs. W. H., Chicago, Ill.
Clark, Arthur L., Hartford, Conn.
Cobb, S. A., Enid, Okla.
Collins, Roy, Okemah, Okla.
Combs, C. G., Turpin, Okla.
Conner, O. L., Tulsa, Okla.
Cook, A. B., Jr., Lansing, Mich.
Cook, Mrs. A. B., Jr., Lansing, Mich.
Cooper, Gerald, Ann Arbor, Mich.
Cooper, Mrs. Gerald, Ann Arbor, Mich.
Cordell, C. R., Fort Smith, Ark.
Cox, Finis, Sallisaw, Okla.
Culler, C. F., La Crosse, Wis.

Dauenhauer, J. B., Jr., New Orleans, La.
Davis, H. S., Washington, D. C.
Davis, Herbert C., San Francisco, Calif.
Davis, Hugh, Tulsa, Okla.
Deaton, W. N., Conway, Ark.
Delman, O. K., Tulsa, Okla.
Denham, S. C., Pittsburg, Kan.
Denmead, Talbott, Washington, D. C.
Detherage, A. L., Tulsa, Okla.
Deuel, Charles R., Gloversville, N. Y.
DeVaunt, Helen, Pratt, Kan.
Domogalla, Bernard, Madison, Wis.

Earle, Swepson, Baltimore, Md.
Eisert, Almeda, Muskogee, Okla.
Ellis, M. M., Columbia, Mo.
Elmore, Pete, Pawnee, Okla.
Eschmeyer, R. W., Ann Arbor, Mich.
Eschmeyer, Mrs. R. W., Ann Arbor, Mich.
Estes, Harvey T., Oklahoma City, Okla.
Evans, Everett W., Collinsville, Okla.
Ewers, Lela, Nevada, Mo.

Faubion, H. E., Austin, Tex.
Ferrell, Mrs. H. S., Neosho, Mo.
Ferrell, Mrs. H. S., Neosho, Mo.
Fiedler, R. H., Washington, D. C.
Finks, Jack, Ada, Okla.
Flickinger, G. R., Tulsa, Okla.
Foster, C. E., Tulsa, Okla.
Foster, Fred J., Seattle, Wash.
French, Harry H., Cache, Okla.
Furrow, Dr. Charles A., Tulsa, Okla.

Gaines, Bill, Bartlesville, Okla.
Gillhan, C. E., Alburquerque, New Mex.
Goddard, C. B., Ardmore, Okla.
Goodwin, W. G., Oklahoma City, Okla.
Gordon, Phyllis, Washington, D. C.
Gordon, Seth, Washington, D. C.
Gordon, Mrs. Seth, Washington, D. C.
Graham, B. S., Oklahoma City, Okla.
Graham, C. A., Jenks, Okla.
Graham, V. C., Tahlequah, Okla.
Gray, A. E., Oklahoma City, Okla.
Gray, R. D., Buffalo, Okla.
Grim, D. N., Glen Eyre, Pa.
Groseclose, Myron, Chichasha, Okla.
Guthrie, Will S., Oklahoma City, Okla.

Hans, Fred L., Pratt, Kan.
Hanson, A. C., St. Paul, Minn.
Harmon, Clay E., Columbus, Ohio
Harrison, A. O., Bartlesville, Okla.
Harrison, Mrs. A. O., Bartlesville, Okla.
Haskin, J. F., Benkelman, Neb.
Hazzard, A. S., Ann Arbor, Mich.
Heines, Ed., Talihina, Okla.
Henderson, W. C., Washington, D. C.
Hennessy, W. J., Chicago, Ill.
Higgins, Elmer, Washington, D. C.
Hill, Frank, Oklahoma City, Okla.
Hill, H. C., Bartlesville, Okla.
Hobo, Bill, Claremore, Okla.
Hodges, R. L., Oklahoma City, Okla.
Hogan, Joe, Lonoke, Ark.
Hogan, Mrs. Joe, Lonoke, Ark.
Holloway, Ancil, Hot Springs, Ark.
Holmes, John Q., Garden City, Kan.
Hubbs, Dr. Carl L., Ann Arbor, Mich.
Hubbs, Mrs. Carl L., Ann Arbor, Mich.
Hunter, R. P., Montpelier, Vt.

Jones, Robert M., Muskogee, Okla.
Jones, Mrs. Robert M., Muskogee, Okla.
Jordan, R. L., Tahlequah, Okla.
Justice, Dr. H. B., Tulsa, Okla.

Kay, Lee, Salt Lake City, Utah
Kelley, Frank M., Muskogee, Okla.
Kidd, Dr. H. R., Okmulgee, Okla.
Kingsbury, O. R., South Otselic, N. Y.
Kohler, M., Lawton, Okla.
Kuhl, Ralph, Enid, Okla.

Lamb, A. R., Little Rock, Ark.
Langlois, T. H., Columbus, Ohio
Langlois, Mrs. T. H., Columbus, Ohio
Larrabee, Lee, Liberal, Kan.
Lawrence, R. F., Youngstown, Ohio
LeCompte, E. Lee, Baltimore, Md.
Leffler, Ross L., McKeesport, Pa.
Little, T. H., Washington, D. C.
Lloyd, Hoyes, Ottawa, Canada
Lockard, Tom, Washington, D. C.
Locke, S. Barry, Chicago, Ill.
Loney, F. Frank, Henrietta, Okla.

McCall, H. G., Little Rock, Ark.
McClanahan, D. H., Sayre, Okla.
McMahan, Boyd, Alltus, Okla.
McMahan, James W., Okemah, Okla.
McMurtrey, M. S., El Reno, Okla.
McMurtrey, Mrs. M. S., El Reno, Okla.
MacKenzie, H. W., Madison, Wis.
Madsen, David H., Salt Lake City, Utah
Manning, Arthur, Medicine Park, Okla.
Manning, Mrs. Arthur, Medicine Park, Okla.
Markus, Henry C., Rochester, N. Y.
Markus, O. W., Metropolis, Ill.
Meade, Lakin, Topeka, Kan.
Meehean, Lloyd, Natchitoches, La.
Meehean, Mrs. Lloyd, Natchitoches, La.
Merritt, J. M., Gretna, Neb.
Miles, Lee, Little Rock, Ark.
Montgomery, Van H., Bartlesville, Okla.
Montgomery, Mrs. Van H., Bartlesville, Okla.
Moore, L. E., Tulsa, Okla.
Morgan, W. H., Tulsa, Okla.
Morgan, Mrs. W. H., Tulsa, Okla.
Morris, R. F., Tulsa, Okla.
Mullen, John, Oklahoma City, Okla.
Murphree, Helen, Durant, Okla.
Murphree, J. M., Durant, Okla.
Murphree, Mrs. J. M., Durant, Okla.

O'Connell, Frank B., Lincoln, Neb.
Owens, Luther, Berryville, Ark.

Parks, Douglass, Chichasha, Okla.
Parris, J. K., Heavener, Okla.
Pautler, J. P., Tulsa, Okla.
Pearson, Dr. T. Gilbert, New York, N. Y.
Penn, George H., New Orleans, La.
Penney, Hon. T. A., Tulsa, Okla.
Piper, Carl, Madison, Wis.
Pitchford, W. O., Chickasha, Okla.
Plott, C. E., Chickasha, Okla.
Powell, Albert M., Baltimore, Md.
Priest, E. C., Pryor, Okla.

Quinn, I. T., Montgomery, Ala.

Rapp, Arthur E., Council Bluffs, Iowa
Reed, Joe, Lawton, Okla.
Reeves, A. R., Oklahoma City, Okla.
Regan, C. C., Covington, Ky.
Regan, Mrs. C. C., Covington, Ky.
Render, C. E., Tulsa, Okla.
Reynolds, R. C., Tulsa, Okla.
Rickey, L. D., Oklahoma City, Okla.
Rodeheffer, I. A., Ann Arbor, Mich.
Rodeheffer, Mrs. I. A., Ann Arbor, Mich.
Ross, J. Walker, Jr., New Orleans, La.
Rudisill, C. R., Austin, Tex.

Sanger, W. S., Oklahoma City, Okla.
Schultz, Leonard, Seattle, Wash.
Sedan, Carl G., Grand Rapids, Mich.
Shoemaker, Carl D., Washington, D. C.
Shutt, Virginia, Pryor, Okla.
Slack, Earl, Tulsa, Okla.
Sloan, Fred, Tulsa, Okla.
Smith, Jim, Tulsa, Okla.
Smith, Marshall, Tulsa, Okla.
Smith, W. C., Bartlesville, Okla.
Spencer, Guy R., Omaha, Neb.

Spicknell, F., Tulsa, Okla.
Stevenson, J. O., Washington, D. C.
Stewart, Dr. R., Okmulgee, Okla.
Strong, Bill, Oklahoma City, Okla.
Surber, Eugene W., Kearneysville, W. Va.
Surber, Thaddeus, St. Paul, Minn.
Swenson, Erling, Minneapolis, Minn.
Sykes, C. E., Ardmore, Okla.

Taylor, Forest E., Oklahoma City, Okla.
Taylor, Mrs. Forest E., Oklahoma City, Okla.
Taylor, H. B., Tulsa, Okla.
Taylor, H. T., Tulsa, Okla.
Thompson, C. F., Springfield, Ill.
Trautman, Milton B., Ann Arbor, Mich.
Tucker, William J., Austin, Tex.
Tumulty, S. I., Tulsa, Okla.
Tunison, A. V., Cortland, N. Y.

Van Oosten, John, Ann Arbor, Mich.
Van Oosten, Mrs. John, Ann Arbor, Mich.
Vanderboort, J. A., Pawnee, Okla.
Viosca, Cranford, New Orleans, La.
Viosca, Percy, Jr., New Orleans, La.
Viosca, Mrs. Percy, Jr., New Orleans, La.
Viosca, Yvonne, New Orleans, La.

Wales, J. H., Palo Alto, Calif.
Walker, C. H., Natchitoches, La.
Walker, Mrs. C. H., Natchitoches, La.
Washington, B. A., Claremore, Okla.
Way, Seth L., Pratt, Kan.
Weber, W. A., Oklahoma City, Okla.
Weems, Ray O., Oklahoma City, Okla.
Welch, W. C., Dallas, Tex.
Westerman, Fred A., Lansing, Mich.
Westerman, Mrs. Fred A., Lansing, Mich.
Wheatley, C. A., San Antonio, Tex.
Wheatley, Mrs. C. A., San Antonio, Tex.
Whitaker, H. L., Stillwater, Okla.
Wiebe, A. H., Austin, Tex.
Wickliff, E. L., Columbus, Ohio.
Wickliff, Mrs. E. L., Columbus, Ohio
Wilkinson, James T., East Lansing, Mich.
Williams, C. A., Wilberton, Okla.
Wooddell, L., Columbus, Ohio

Young, E. C., Ottawa, Canada

REPORT OF OFFICERS

REPORT OF THE SECRETARY-TREASURER

For the Year 1934-1935

SETH GORDON

Through the cooperation and efforts of its members, the Society added 115 new active members and two clubs to its roster during the past fiscal year. This is a gain of 38 over the preceding year.

While we showed a material gain in the new members, I regret to report that our losses were heavier than for the previous year. We were compelled to drop fifty active members and one club for non-payment of dues. The resignations this year also showed an increase, the Society losing fifteen active members, two clubs and one library, and death took its toll of nineteen, making a total loss of seventy-nine.

This leaves the Society twenty-nine members ahead for the fiscal year, July 1, 1934 to June 30, 1935, a gain of only four members over the previous period. It is regrettable that so many of our members must be dropped annually. This year a special effort was made to reduce this loss by writing each delinquent a special letter. A goodly number responded favorably, but the number lost annually is still too large in proportion to the Society's new enrollments.

You will note that we did not have the privilege of adding any new state memberships during the year, although four have been received since the close of the fiscal year. The Society's membership is particularly weak in this respect. Every state and province should maintain a membership in the Society, and urge its fisheries employes to join, too.

Below I am submitting a statement of the business transactions for the fiscal year, which closed June 30, 1935.

In this period you will note that we paid for the printing of the 1933 Transactions, and $1,455.75 on account for the printing of the 1934 volume leaving a balance of $525.00 still to be met. Through the approval of the members of the Council, $500.00 was transferred from the Permanent Fund income to help defray some of the unusual expense incident to printing the 1934 Transactions, an unusually large volume.

Each year the size of the Transactions seems to increase, and the cost mounts up. Unless the length and number of the papers are materially reduced, the alternative will be either to increase the membership fees or greatly to enlarge the membership. The Society cannot afford to distribute the Transactions at the present cost per copy, $2.75 exclusive of mailing charges, for the present membership fee. I am confident that we are getting the best price on producing these Transactions for the quality of the work. If compelled to do so, we can resort to cheaper workmanship and stock, smaller type and other economies, all of which would detract from the appearance, usefulness, and durability of the Transactions as a reference volume.

At the close of the previous fiscal year the Society had no outstanding indebtedness, but at that time the bill for printing the 1933 Transactions, amounting to $1,241.53, had not been rendered. At the close of this fiscal year our outstanding obligations amounted to the $525.00 already mentioned.

TREASURER'S REPORT

July 1, 1934 to June 30, 1935

General Fund

Receipts		
Balance on hand July 1, 1934		$ 595.45
Annual Dues:		
Individuals and Libraries		
For the year 1932-1933	$ 9.00	
1933-1934	81.00	
1934-1935	1,361.00	
1935-1936	213.00	1,664.00
Clubs and Dealers		
For the Year 1933-1934	5.00	
1934-1935	135.00	
1935-1936	40.00	180.00
State Members		
For the year 1933-1934	30.00	
1934-1935	200.00	
1935-1936	30.00	260.00
Sale of Transactions		372.21
Sale of Separates		
1933 Transactions	313.54	
1934 Transactions	11.00	324.54
Sale of Index		5.00
Exchange on checks		.65
Transferred from accumulated income of Permanent Fund		500.00
Refund American Game Association		1.00
Total Receipts		$3,902.85
Disbursements		
Transactions		
1933, vol. 63		
Printing	$1,159.00	
Separates	370.93	$1,529.93
1934, vol. 64		
Printing	1,455.73	
Reporting	133.50	
Additional proofreading assistance	31.50	
Indexing	70.80	1,691.53
Postage		
Secretary's office	181.29	
Librarian's office	10.00	191.29
Rental safe deposit box		5.50
Office supplies		3.98
Stationery and printing		52.65
Express		8.38

Clerical and secretarial expense		
American Game Association	100.00	
Ethel M. Queçe	150.00	
Seth Gordon	100.00	350.00
Traveling and entertaining		9.35
Premium on bond		5.00
Miscellaneous		21.00
Telephone		3.30
Exchange on checks		1.84
Tax on checks		.36
Total Disbursements		$3,874.11
Receipts General Fund	$3,902.85	
Disbursements General Fund	3,874.11	
Balance on hand July 1, 1935		$ 28.74

NOTE: For the further information of the members of the Society, during the period of July 1 to September 3, we had receipts of $1,017.53, and expended $563.92, leaving a balance on hand in the General Fund of $482.35 as of September 3. During this same period we received 13 individual and 4 state applications for membership, with numerous others presented since arriving in Tulsa.

PERMANENT FUND

RECEIPTS

Balance on hand July 1, 1934		$ 277.15
Interest on savings account	$ 9.81	
Interest on Title Guarantee & Trust Co. Certificates and N. Y. Title & Mortgage Certificates	301.52	
Dividends on Commonwealth Southern, pfd.	52.50	363.83
Total Receipts		$ 640.98

DISBURSEMENTS

Accumulated income transferred to General Fund with approval of the Council	500.00
Balance on hand July 1, 1935	$ 140.98
Par value Certificates Title Guarantee & Trust Co.	$4,000.00
Par value 10 shares Commonwealth Southern, pfd. @ $100 each	1,000.00
Par value Certificates of N. Y. Title & Mortgage Co.	1,000.00
Total	*$6,000.00

*The market value of Certificates of Guarantee and Trust Co. and N. Y. Title and Mortgage Company during the past year has been far below par, but since there is no open market no established cash value is available. The cash value of the 10 shares of Commonwealth Southern Preferred, par value $100, as of June 30, 1935, was $465.

The report of the Secretary-Treasurer was received and referred to the Auditing Committee. Upon the approval of the committee, the chairman of which stated he had also checked over the Permanent Fund Securities of the Society, the report was later accepted as submitted.

REPORT OF STANDING COMMITTEES

REPORT OF MEETING OF THE COUNCIL OF THE SOCIETY

The Council of the American Fisheries Society met at the Hotel Mayo, Tulsa, Oklahoma, at 8:30 P. M., September 8, 1935, members present being E. L. Wickliff, president; Frank T. Bell, vice-president; Seth Gordon, secretary-treasurer; and I. T. Quinn, Thaddeus Surber and S. B. Locke of the executive committee.

Others present by invitation were division vice-presidents as follows: A. B. Cook, Fish Culture; A. H. Wiebe, Aquatic Biology and Physics; and Talbott Denmead, Angling; also Fred Westerman, the president of the Society last year.

The minutes of the meeting of the Council last year were reviewed and discussed, as were the plans for the sixty-fifth annual meeting.

The general problem of handling the large volume of papers was discussed at length. It was decided that the plan adopted as to length of time allowed for the presentation of papers at the sixty-fifth annual meeting, and the number of papers one author may present, be continued.

It was further moved and agreed to that in the future all papers must be in hand at the time and place of the meeting in order to be eligible for printing in the Transactions, subject, however, to prompt necessary revisions by the authors following the meeting.

The desirability of papers not bearing directly upon the work of the Society was considered, and it was agreed that in the future such papers shall be eliminated to help keep the Transactions within reasonable size.

The transfer of $500.00 from the accumulated income in the Permanent Fund to make up the deficit in the General Fund, incurred by the large size of the 1934 Transactions, previously authorized by mail, was formally approved. The Council did not deem it wise to restore this amount to the Permanent Fund at this time.

The Committee on Abstracts from foreign fisheries literature, consisting of Messrs. J. A. Rodd and Herbert C. Davis, was continued, with an appropriation of $100.00 from the Permanent Fund income for its use.

At a later session of the Council suggested revisions in the by-laws, presented by T. H. Langlois, chairman of the special committee appointed for that purpose at the last annual meeting, were considered and approved for submission to the Society.*

Seth Gordon, *Secretary.*

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*Under the revised by-laws adopted at the final business session of the sixty-fifth annual meeting, the Council as heretofore constituted was dispensed with and the Executive Committee, now consisting of the officers, the division vice-presidents, and the president of the previous year, functions in its stead.

REPORT OF THE COMMITTEE ON FOREIGN RELATIONS

J. A. RODD, *Chairman*

Your Committee is in the happy position of being able to report a continuation of the cordial foreign relations that were mentioned in its report for last year. The treatise and agreements then referred to are still in effect, and there is no fishery question of major importance in the boundary waters of the United States and Canada, nor in those portions of the high seas where the nationals of the two countries have a common interest, in which agreement as to what should be done has not been reached, or which has not been investigated, or is in process of investigation in order to ascertain a sound basis of agreement.

Prior to 1911 the fur seal herd that breeds on the Pribilof Islands had become almost negligible from a commercial point of view, having been reduced to a low level of between 125,000 and 136,000 animals. With a view to rehabilitating this herd, the Pelagic Sealing Treaty of 1911 was entered into by the United States, Great Britain, Japan and Russia. As a result the seal herd, according to the recent estimate of the United States Government, is now in excess of 1,300,000 animals, which permits of an annual take of well over 50,000 skins of surplus males.

The northern Pacific halibut fishery did not begin to assume any considerable importance until the early nineties of the last century, when reasonably good transportation facilities from the West Coast to the eastern markets of North America became available. The fishery then expanded very rapidly until it soon became the most important halibut fishery in the world. By 1909 or 1910, however, unmistakable evidences that fishing was being overdone were becoming apparent. During the next decade those engaging in the industry in a large way, realizing that the fishery was being over-exploited, began to urge that action be taken to prevent its depletion. In 1917 the International Commission, appointed to consider the settlement of outstanding fishery questions between Canada and the United States, recommended that a treaty between the two countries be entered into that would provide for a closed season of three months on halibut in the north Pacific, and for the appointment of an international commission to investigate the natural history of the halibut in this area to report to the two governments what would be necessary for the maintenance and development of the fishery. Effect was given to this recommendation when a treaty was signed in March, 1923, which became operative October, 1924.

The International Fisheries Commission or, as it is popularly known, the Pacific Halibut Commission was set up under the treaty and charged with the duty of making a thorough investigation into the life history of the Pacific halibut, and of making recommendations to the two governments for such regulation of the fishery as might be desirable in the interests of conservation and development. Subsequently—in May, 1931—a new convention was ratified, differing from the first treaty mainly in that it gave power to the Commission itself, subject to the approval of the Governor in Council and the President of the United States, to make regulations

governing the fishery. This power has been exercised by the Commission from time to time in such ways as study of the fishery has shown to be expedient.

A brief reference to fishing results will show in sharp outline the beneficial effects which are flowing from international regulation of this important fishery. Prior to 1930 the production from the older areas of the treaty waters had fallen to about one-sixth of what it had been some twenty years before. Over-fishing was leading to depletion. In 1930, as shown by Commission records, the catch per unit of gear in these older areas was 35½ pounds. By 1934, however, the catch per unit of gear on these grounds had risen to more than 50 pounds. In other words, intelligent regulation of the fishery by closing "nurseries" to fishing operations and by controlling production from open areas has not only checked the decline which was formerly apparent but it is bringing about a most satisfactory degree of restoration.

Another example of international cooperation may be seen in the International Pacific Salmon Federation which correlates the results of North American investigations in regard to Pacific salmon and thus helps to prevent unprofitable duplication of research effort by the Dominion and the United States. The Federation is made up of representatives of the two national fisheries departments and representatives of the departments in the states of California, Oregon, and Washington, the province of British Columbia, and the territory of Alaska.

Reference may also be made here to the fact that a revival of interest has been apparent in various quarters as to the possibility of restoring to its former size the sockeye salmon run to the Fraser River and to Puget Sound, a subject which concerns both the United States and Canada. A treaty, with restoration as the end in view, was signed at Washington in May, 1930, by the Canadian Minister to the United States and the Secretary of State for the United States but, although it was approved by the Canadian Parliament some time ago, it has not been ratified by the Senate of the United States on behalf of that country.

During the last fifty years some nineteen interstate and international conferences have been held on the Great Lakes to consider remedial measures to check the depletion of the very valuable fisheries of these inland seas and to restore and maintain their productivity. The Great Lakes Conservation Council, composed of representatives from the Department of Fisheries, Ottawa, the Bureau of Fisheries, Washington, D. C., the province of Ontario, and each of the states interested in the fisheries of the Great Lakes, has held several conferences in regard to this most important matter. The Lake Erie Advisory Committee, an offspring of the Council, is continuing the former's efforts and has contributed in a marked degree towards securing uniform regulations for Lake Erie as well as for the Great Lakes generally.

The pike-perch fishery of Missisquoi Bay and Lake Champlain is also the subject of an investigation by an International Fact-Finding Commission appointed by the United States and Canada.

The International Commission appointed by these two countries to investigate the probable effects of the damming of Passamaquoddy and Cobscook bays on the fisheries of that region submitted its report last year.

A further conspicuous example of cooperative international effort is seen in the North American Council on Fishery Investigations which is a deliberative body made up of members appointed by the governments of the adhering countries, namely, Newfoundland, France, the United States and Canada. The Council was established in 1920 and usually meets in alternate years in Canada and the United States. It coordinates fisheries investigations in the western north Atlantic, correlates the results of such research, and facilitates the exchange of scientific information amongst the countries concerned. In 1934 the Council met at Halifax on board the French Government's fisheries research vessel *President Theodor Tissier*, which came into Halifax for the purpose with a group of French scientists. This year's meeting, the twenty-second in the history of the Council, will be held at Washington on September 17-19.

The Multilateral Convention for the Regulation of Whaling was signed on behalf of Canada at Geneva, September 24, 1931, and was ratified at the last session of the Canadian Parliament. Provisions of this Convention have in effect been applied to the Canadian whaling industry since 1933. The Convention was ratified by the United States Senate on July 10th, 1932, and the international requirements and conditions involved in it were complied with by all signatory powers on November 11th, 1934, when the provisions automatically went into effect.

Your Committee urges this Society to continue to support to the best of its ability in the future, as it has done in the past, the practice of seeking the solution of all international problems through international investigation.

REPORT OF THE COMMITTEE ON RELATIONS WITH FEDERAL, PROVINCIAL AND STATE GOVERNMENTS

Charles E. Jackson, *Chairman*

More progress has been made the past year in increasing fish propagation facilities in the United States than at any previous time in the history of the nation. Under the leadership of President Roosevelt, there has been an awakening of interest in all conservation matters and through the use of emergency federal funds fish propagation facilities of the federal government and of the states have been considerably increased. While these facilities have increased production, at the same time there has been a tremendous increase in water areas that will require stocking.

It is doubtful whether the increased production facilities have kept pace with the creation of new water areas. Reports from both the federal and state governments indicate that the demand for fish is still greater than the supply. The real problem in fish culture is the continuous administration of these new fish cultural facilities that have been provided during the emergency period. Every effort should be made by the state and federal

governments to follow through on these various plans. It will be difficult to secure the necessary funds to maintain and operate these facilities but, unless a backward step is to be taken, it is imperative that the necessary funds be provided.

Through the use of emergency funds much has been accomplished in stream surveys and studies of watersheds. Stream surveys conducted by the federal government in the National forests have covered one-sixth of the total area. This has been followed by stream improvement and a program of scientific fish planting. Many of the states have carried on similar projects. The effect of stream improvement has not yet been determined fully but it is apparent that well organized fish cultural programs of the future will follow a plan of survey, improvement and balanced stocking, rather than merely stocking, as has too often been the case in the past.

The Bureau of Fisheries reports an increased production and distribution of fish and eggs, including fry hatched on a cooperative basis in state hatcheries approximated at 5,000,000,000 in comparison with an output of 3,258,000,000 for the previous year. Most of this increase was in the production of commercial fish, the game fish production being approximately the same as the previous year with the exception of smallmouth black bass, which was almost twice the production of the previous year.

The subject of pollution has received wide attention during the past year and efforts have been made to have the federal government take cognizance of the serious situation and to develop plans for the abatement of this nuisance on a national scale. Legislation was passed by Congress authorizing the states of New York, New Jersey, and Connecticut to enter a compact or treaty among themselves to attack the pollution problem. The Bureau of Fisheries has established two small motive laboratories under the direction of Dr. M. M. Ellis so that it is now possible to move a laboratory and scientific crew to the scene of complaint, and in a comparatively short time to determine the cause and effect of pollution and to make recommendations for the correction of the same. The National Resources Board has had the matter under study and it is hoped will provide some means to improve the pollution problem in the near future.

Through the National Planning Council of Commercial and Game Fish Commissioners, organized by the U. S. Commissioner of Fisheries and composed of the Federal and State Game and Commercial Fish Commissioners, a cooperative program between the states and the federal government has made great progress which has resulted in economy of administration and closer coordination of fishery activities. Cooperative fish culture work with the federal government is now being conducted in forty states. Technological and scientific cooperative agreements are now being carried on by the Bureau of Fisheries with the University of Maryland, University of Michigan, University of Missouri, Amherst, University of Washington, State Medical College of South Carolina, Harvard University, Yale University, Stanford University, University of Utah, Wisconsin University, Middlebury College, and Duke University. In the state of New York the agreement includes the Bureau, Cornell University and the New York State Conserva-

tion Department. As a result of the Coordination Act of Congress, the various branches of the Federal Government engaged in Conservation are improving the coordination of their activities.

In the enforcement of the Federal law, regulating the interstate transportation of black bass, 110 game wardens located in 31 states have been appointed as deputy black bass law inspectors by the Secretary of Commerce to assist in enforcement of the law.

The Great Lakes Fisheries situation has not shown any improvement during recent years, in spite of the fact that every effort has been made by the federal government and by the Fish Commissions of the various states having jurisdiction over these waters. The danger of depletion of valuable food fishes in the Great Lakes is one of the most serious problems confronting the North American fisheries today. Uniform laws and regulations to apply to all states and provinces fishing a given lake is essentially needed but little progress to this end has been made. Many conservationists have expressed the opinion that the Great Lakes Fisheries can only be efficiently regulated under federal or treaty control.

The problem of preventing the depletion of fish is even more serious today than ever before. Every modern means of transportation is utilized to pursue the fish. Few realize that the rapid development of the outboard motor, the automobile, and the airplane, coupled with the extension of a gigantic highway system, has resulted in the penetration of forests and streams that have since the beginning of time been a natural haven and refuge for fish. A vast domain which has heretofore been inaccessible to man is now open for his exploitation. With the exception of those areas closed to fishing by law, there is virtually no fishing ground left on the American continent which can not be reached by modern transportation. More attention must be given in the future to the establishment of closed areas and the setting aside of regulated sanctuaries for fish. Advancement of civilization means the exploitation of natural resources. The drain on the fisheries resulting from modern transportation and from pollution are the two major problems that must be solved in the preservation and restoration of aquatic life.

COMMITTEE ON THE COMMON AND SCIENTIFIC NAMES OF IMPORTANT NORTH AMERICAN FISHES

CARL L. HUBBS, *Chairman*

The following resolution was proposed and adopted during the 1932 meeting of the Society:

WHEREAS, A wide diversity exists on this continent in the use of the common names of fishes, and

WHEREAS, Such diversity of usage leads to much confusion in fish-culture problems and legislation,

BE IT RESOLVED, That a permanent Committee be appointed by the Executive Council of this Society to prepare and submit for publication a list of standard, common names corresponding to the accepted scientific names, and that the said

Committee have power to add to this list from time to time, as proves necessary.

And Be It Further Resolved, That the members of the American Fisheries Society adopt the use of these names in general practice and urge their universal employment in all legislation.

The Council of the Society in 1933 organized this Committee with the following membership: E. L. Wickliff, Samuel F. Hildebrand, Wm. J. K. Harkness, John O. Snyder, and Carl L. Hubbs as Chairman. In 1934 Walter H. Chute and A. H. Leim were added to the Committee.

Pressure of other duties and absence on collecting trips has prevented the Chairman from completing a list for the consideration of the Committee, but he hopes to have such a list ready for presentation at the 1936 meeting. The cooperation of all American fishery workers and ichthyologists in the selection of generally acceptable names is requested.

The Committee, with the concurrence of the officers of the Society, has agreed to several points of policy, namely: (1) to limit the area covered to North America north of the Mexican border; (2) to treat only those species which are of some commercial or angling interest, including important forage fishes, rough fishes, fish predators, and such other species as possess sufficient general or popular interest as to warrant their inclusion; (3) to propose a single name for any given species, mentioning other generally used names, for sake of clearness, in smaller type; (4) to give the currently accepted scientific name for definiteness of determination; (5) to eliminate descriptions, illustrations and scientific synonymies; (6) to prepare three separate lists, one for each coast and one for the fresh waters of the continent.

REPORT OF THE AMERICAN FISH POLICY COMMITTEE

E. L. Wickliff, *Chairman*

Your committee begs to report that it has agreed upon the following basic essentials, and will submit its completed report at a later meeting:

I. A North American Fish Policy must be international in scope and application.

II. It should define the spheres of activity of, the nature of the work or services to be rendered by and the relationship between the Federal or Dominion and the State or Provincial governments with respect to both sport and commercial fisheries, in marine and fresh waters, in boundary and non-boundary waters. The following points should be considered:

1. Administrative control of and enforcement on boundary waters and on non-boundary waters on federal lands.
2. A cooperative policy in regard to propagation and distribution of fish.
3. Cooperation in research projects and experimentation.
4. Cooperation in the dissemination of reliable information on fish and fisheries.

III. It should outline broad objectives for future fisheries administration and management. The following points should be considered:

1. It should provide for specific consideration by National, State, and regional planning boards of the development and conservation of the fishery resources as an independent element of national wealth and not as a minor incident to the planning of recreational facilities as has been done in the past.
2. It should provide for the recognition of the principle of prior right for the fisheries in all reclamation, drainage, irrigation, flood control, or water power development by all official boards concerned with the planning of land or water use and the development of natural resources.
3. Public ownership of lands based on fishing waters as well as on forestry, game, watershed, parks, and recreation.
4. Public fishing rights on private waters acquired by lease, purchase, or otherwise.
5. Management of public fishing waters.
6. The fisheries as a profession like forestry and agriculture.
7. Creation of facilities to train men especially equipped for this profession.
8. Political interference.
9. Funds obtained by general taxation as well as by licenses.
10. Cooperation with owners of private waters, sportsmen, commercial fishermen, educational institutions, institutes, and experiment stations.
11. Educational and advertising campaigns.
12. The fisheries as crops.
13. Provision for private propagation for commercial purposes.
14. A balanced fisheries program involving restrictions, enforcement, propagation, environmental control, introduction of exotic fish, predator control, refuges, statistics, natural histories of fish, and fish food.

IV. It should set up fishery research objectives. The following points should be considered:

1. Lake and stream surveys and improvements.
2. Research on maximum productivity of lakes and streams.
3. Soil erosion and reforestation.
4. Drainage, flood control, water restoration and impounded waters.
5. Fishways and screens.
6. Statistical surveys of abundance including creel census.
7. Improvements in fish cultural methods.
8. Proper stocking policies and standards.
9. Closed seasons and the permit system.
10. Nurseries and refuges.
11. Life histories and natural histories of fish.
12. Predator control.
13. Parasites and disease.
14. Improvement in commercial fisheries gear and technique and the

grading, marketing, and distribution of commercial fisheries products.

V. It should define the essentials of a pollution policy.

VI. It should define the policy with reference to uniformity of laws between the various States or provinces and between the United States, the Dominion of Canada and the Republic of Mexico governing both game and commercial fishes.

VII. It should discuss discretionary powers with reference to both sport and commercial fisheries.

VIII. It should refer to the standardization of common names of fishes similar to that provided for birds.

IX. It should refer to the question of introduction of exotic species of fish.

X. It should consider the advisability of including forage fishes, mussels, oysters, and other fisheries products that do not involve the fishes.

NOTE: It should provide for the appointment of sub-committees to correlate and summarize at irregular intervals the most recent data and information on various fisheries and pollution problems and to outline methods of research.

It should provide for very close cooperation between the Committee on Fish Policy and the Committee on Game Policy whenever their objectives are closely interwoven, such as the acquisition of public lands and watersheds, the impounding of waters, etc.

PRELIMINARY REPORT OF THE POLLUTION STUDY COMMITTEE

TALBOTT DENMEAD, *Secretary*

A great deal of time and thought has been given by various agencies and individuals interested in the general subject of proper methods for preventing pollution and cleaning up our streams. The members of the American Fisheries Society's Pollution Study Committee have given the whole subject much study individually, but the Committee is not yet ready to submit its final recommendations.

Among the most important actions taken during the past year may be mentioned the work of the Committee headed by Senator Lonergan, the investigations of the National Resources Board, and the Mansfield Bill filed by Congressman Joseph Mansfield for preventing wastes being thrown into navigable waters. It is the intention of this report to outline the highlights of the Lonergan Report and the Mansfield Bill and other important actions. The National Resources Board Report has not yet been made available to the general public.

THE LONERGAN REPORT

Senator Augustine Lonergan called a meeting in Washington, D. C., December 6, 1934, for the purpose of bringing together experts and leaders from various parts of the country to express their views as a basis for further action. It was attended by the Secretary of War and other government officials, including, Brigadier General G. B. Pillsbury, U. S. Army; Frederick A. Delano, Vice Chairman, National Resources Board; Senator Lonergan; Commissioner Frank

T. Bell, U. S. Bureau of Fisheries; Charles E. Jackson, Deputy Commissioner, U. S. Bureau of Fisheries; Congressman A. Willis Robertson, Chairman, House Wildlife Committee; R. E. Tarbett, Chief Engineer, U. S. Public Health Service; J. N. Darling, Chief, U. S. Biological Survey; General S. N. Wadhams, Director, State Water Commission of Connecticut; also Lewis E. Tifft, Esquire, Kenneth A. Reid, Dr. M. D'Arcy Magee, Grover C. Ladner, Carl D. Shoemaker, and many others.

Much testimony was submitted. Resolutions were also submitted, copies of which were forwarded to members of the American Fisheries Society Pollution Study Committee in the minority report of the sub-committee of Stream Purification Conference. Additional copies may be obtained from your secretary. Briefly it recommended Federal control.

The printed report, Document No. 16, 74th Congress, 1st Session, January 30, 1935, may be obtained from the office of Senator Lonergan; it is, therefore, not necessary to quote it herein. However, a letter dated January 25, 1935, from Senator Lonergan to Honorable Harold Ickes, Chairman, National Resources Board, is quoted in part:

> "I have been informed by the Secretary of War that the National Resources Board is now taking definite steps through its Water Resources Section in planning water pollution control measures in cooperation with Federal, State, and local agencies. He states that the advisory committee of the Board has approved an intensive program of water-pollution activities under the direction of a special committee of the Water Resources Section, composed of representatives of the Federal agencies, and that initial work of this committee should be completed in time to formulate definite recommendations to Congress.
>
> "Secretary Dern suggests that in view of such action, the adoption of either the majority or minority reports of the Stream Purification Conference of experts which was called on December 6, 1934, would appear to be premature, and that introduction of any legislation based thereon, might conflict with the program which will be recommended by your special committee when it has completed its studies.
>
> "In compliance with his suggestions, I am, therefore, temporarily delaying further active steps on this matter but wish to point out for your guidance in preparing your program, the mandate of the experts of our conference, who voted in favor of a general plan, thus far described as the "minority plan." A copy is enclosed for your study.
>
> * * * * * * *
>
> "In view of this mandate, I am sure you will feel the responsibility, as I do as Chairman of the Conference, of making your plan comply essentially with that which they have laid down if we are to have their cooperation.
>
> "I will thank you if you will submit your report to me on this subject as promptly as possible, and in view of its importance, I invite you to forward to me, if you will, a preliminary draft of your plan before it is actually placed before Congress. I feel a personal responsibility to the conferees in this matter in carrying out their mandate."

The Mansfield Bill

On July, 30, 1935, Congressman Mansfield introduced in the 74th Congress, 1st Session, by request, a bill to prevent pollution of the navigable rivers and harbors of the United States.

Briefly this bill makes it unlawful to deposit any refuse matter or waste in any navigable waters of the United States, or where it can flow or be washed into such water. The balance of the 9-page printed bill is devoted principally to the manner of administration.

The Secretary of War is empowered to serve a complaint on offenders who shall have a right to show cause why an order should not be entered requiring them to stop the act or practice charged in the complaint. The person so ordered may obtain a review of the order in the Circuit Court of Appeals of the United States.

Failure to obey any order of the Secretary, the offender shall forfeit $100.00 for each day during which such failure to stop waste running into the water continues.

It defines navigable waters as waters over which Congress has jurisdiction under its authority to regulate commerce. It defines "refuse matter, or waste of every kind or character," as including oil, raw sewage, coal mining washery waste, acid mine drainage, coal distillation waste, pickling and plating waste, pulp or paper manufacture waste, tanning waste, and washing, bleaching or dyeing waste.

The Secretary is empowered to subpoena witnesses, administer oaths, require production of books, etc.

This bill was not acted upon by the Congress at the recent session and it is hardly likely it will prove satisfactory to those interested in seeing pollution eliminated. Certainly it will not receive any backing from those now dumping refuse into our navigable waters. As it was filed "by request," it is safe to say the bill stands little or no chance of passage at the coming session of Congress. As now drawn it might be construed by some to apply only to those pollutions that are a menace to navigation.

Report of National Resources Board

While it is understood that a report by this Board has been formulated by a sub-committee of the Committee appointed to make a study of this subject, the Committee has not met and, therefore, its findings cannot be made public at this time. However, should the Committee meet, whatever information may be released will be forwarded to your Secretary at Tulsa.

Sealing of Abandoned Mines

The question of sealing abandoned mines has been given much consideration in the past year and something has been accomplished by the sealing of a large number of mines which have been discharging acid into streams to the detriment of fish life in the States of Ohio, Iowa and West Virginia. Through the efforts of Mr. Kenneth A. Reid, of Pennsylvania, various members of the American Fisheries Society, and others, Federal money was earmarked for this work. A report on the mine sealing has been prepared by Mr. Reid and is available

through the American Game Association. We regret that the funds originally allocated by the Public Works Administration for this were seriously reduced and it is hoped a way will be found to obtain additional funds and seal up more abandoned mines. The Committee calls special attention to the fact that it was only a little over a year ago that Mr. Leitch of the U. S. Bureau of Mines discovered the method of handling mine drainage to remove the acid poison and purify the water coming from abandoned mines.

In West Virginia there was a total of 3,523,500 pounds of mine acid discharged daily into the streams from 1,440 mines, only 31 per cent of which were active. Of this total discharge 222,525 pounds discharged per day have been removed by the sealing of 215 mines in this state. Progress has also been made in the other states mentioned.

Sewage Systems with Federal Funds

It is amazing how many cities and towns have no sewage systems but still depend on rivers and streams to carry off all or part of their domestic sewage. However there has been a decided improvement during the past year and many municipalities have availed themselves of Federal funds to install sewage systems or build disposal plants.

The Public Works Administration advises there have been 562 non-federal sewage projects financed at a cost of $140,204,000; and 59 Federal projects at a cost of $2,695,000, or a total of approximately $143,000,000 allocated for sewage systems and disposal plants. Of the total 621 projects, 163 were disposal plants and 458 sewage systems. While this leaves many large cities and towns still offending, it has cleaned up an immense amount of domestic pollution.

The National Capitol is the outstanding example among those cities now dumping raw sewage into nearby waters that have secured the funds for a system which will take care of the city's needs for the present at least.

U. S. Bureau of Fisheries

The U. S. Bureau of Fisheries has been actively engaged in pollution investigations to determine the effect of stream pollution on aquatic life, and has taken part in various plans for cleaning polluted waters. Its representatives have attended nearly all the important meetings on the subject and it has lent its moral support to those actively engaged in obtaining funds for sewage systems, or cleaning polluted waters by other means.

Senator Hawes Chapter on Pollution

Our Chairman, Senator Hawes, has devoted a chapter in his recently completed book on Conservation to the subject of "Pollution and Its Consequences," which is an able review of the subject. While the book has not yet been published, copies of the chapter on pollution have been made available to your Committee for its information.

S. J. Resolution 159

Congress adopted a Resolution (S. J. Res. 159) authorizing the States of New York, New Jersey, and Connecticut, to enter into a compact for the creation of

the Interstate Sanitation District and the establishment of the Interstate Sanitation Commission, a copy of which is in the files of your Committee.

The Interstate Sanitation District includes all the coastal, estuarial and tidal waters within or covering portions of the signatory states, and among the waters included are: Long Island Sound and the Housatonic River, all of the tidal waters of Greater New York City, the Atlantic Ocean, and the estuaries and tidal waters thereof between the New York City line and the easterly side of Fire Island Inlet, the Hudson River and estuaries and tidal waters thereof between the New York-New Jersey State boundary and the northerly line of Rockland County on the westerly side and between the northerly line of New York City and the northerly line of Westchester County on the easterly side of the river; the Hudson River and New York Upper Bay in New Jersey and estuaries and tidal waters thereof, the Passaic River, Newark Bay, the Raritan Bay and River, the Cheesequake Creek, Matawan Creek, Sandy Hook Bay and Shrewsbury River. The parts affected are definitely designated in the Resolution and your attention is invited to it for more details.

Conclusions

It would seem that there have been enough investigations, both in this country and abroad, to know what pollution is, and the remedies therefor. The problem now appears to be a legal one—how to suppress future contamination of water by laws which can be enforced.

There seems to be a definite trend of sentiment towards federal control as the states have not up to the present time appeared to be able to handle the situation, or have not done so for other reasons.

It appears, therefore, that for the American Fisheries Society to recommend at this time a federal control program, or any other program, would not accomplish our purpose. It does not seem wise to the committee to draw up a report to the Society for consideration of a Pollution Bill to be presented to Congress at this time. It does desire to make one recommendation at this time, which will also be presented to you in the form of a Resolution.

As a matter of policy your committee does recommend at this time that in the framing of legislation now pending or contemplated and in the drafting of recommendations by federal and state agencies relative to water purity standards to be met or maintained in public waters, that conditions not merely sublethal, but favorable to all stages of the desirable food and game fishes of the particular region, and to those aquatic organisms both plant and animal which comprise the food and food chains of these fishes *be required;* i.e., that, in such public waters as may reasonably be expected to support desirable fishes, the limitation or treatment of pollution merely to produce those barely sublethal conditions under which some species of fish can exist, even though the water be rendered useable for industry or potable for man, does not constitute a suitable or satisfactory environment for desirable food and game fishes, and consequently cannot be approved by fisheries interests.

It would seem more sensible for it to make a Progress Report now with the suggestion that this Committee be continued, or a new committee be appointed

to take its place if the incoming President feels inclined to appoint his own committee or to make changes in the personnel of the present one.

It is, therefore, recommended by your Committee that the committee appointed at Montreal, Senator Harry B. Hawes, chairman, be continued, and that a further study be made of this pollution problem with a view to the recommendation to this Society either previous to, or at its next annual meeting, of some method of control, not yet agreed upon by the various interests and organizations involved.

If the Society desires to do so, the resolution extend the life of the Pollution Study Committee might well authorize it to submit to Congress its recommendation for remedial action at the same time its report is submitted to the officers of the Society.

The officers of the present committee have not been idle during the past year but have accumulated a vast amount of information on pollution which is on file in the office of the committee in Washington, D. C.

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF THE VICE-PRESIDENT OF THE DIVISION OF FISH CULTURE

A. B. Cook

There appears to be a growing sentiment on the part of various members of the Society that any report of a divisional Vice-President should be merely a summary of the important developments in his field during the preceding year. With this in mind, communications were sent to all those charged with the administration of fish cultural units in the United States and Canada, requesting information on progress and experiments made during the past year. Due to restricted time, it will be impossible to comment on all of the changes reported. It will be my purpose to outline briefly those seemingly important points which are receiving quite general attention.

The older members of the Society will recall, and those who are younger surely have read, of the fry-fingerling controversies, which were waged over a period of years. That matter, which was never settled, was finally legislated from further consideration by the Society. And once again, if the letters received from the various states and provinces serve as a criterion, a new set of problems arise as subjects for plenty of differences of opinion among Society members.

For example:

Fingerling vs. adult fish culture;
Intensive vs. extensive policy of pond culture;
Respective merits of stream and lake improvement devices;
Various methods of transportation.

These and many others will be debated at this meeting, and others to come. Due, probably, to a bit broader viewpoint made possible by the diversified interests of our members, we hope there will never again come a time when it will be necessary to outlaw any specific subject.

There seems to be a universal interest on the part of all executives to find desirable substitutes for conventional fish food, due to the advance in prices. It is hoped that some findings of real significance will result from the united effort in this field.

The several federal agencies have done much to expand and improve physical plants in many states. This has been estimated in some cases to be equal to twenty-five years of normal development, and those who took advantage of the opportunities afforded by Federal Works Programs are to be congratulated.

From the material submitted to me, I gather there are about four important problems confronting the modern fish culturist:

First:—There is a grave need for uniformity of standards for basing results of output and cost computations. A step in that direction already has been made by Langlois of Ohio, but many feel that this matter should be extended to trout as well as bass breeding.

Second:—Several states have created biological stations which specialize in practical phases of scientific work. This serves to amplify the importance of the scientist in working out many of the problems pertaining especially to the dietetic and pathological phases of our work.

Third:—A genuine interest in determining the effect of artificially altered environmental conditions upon fish life has manifested itself upon the consciousness of the fish culturists. The CCC, which has fostered a real comprehensive experiment in this particular, is largely responsible.

Fourth:—The modern fish culturist is not so much concerned with the raising of fish as he is with the development of good fishing. The furtherance of this attitude probably is the greatest contribution which the Society can make toward a permanent fisheries policy for North America.

REPORT OF THE VICE-PRESIDENT OF THE DIVISION OF AQUATIC BIOLOGY AND PHYSICS

Dr. A. H. Wiebe

I have not prepared a formal report, but it might interest you people to know that there has been an awakening in Texas of interest in the possibilities represented by hundreds of miles of shore line on the Gulf of Mexico for the development of the aquatic resources of that region for both cultural and economic purposes. The people at the universities and colleges of Texas have finally come to the realization that certain opportunities are represented by their coast line and coastal waters and that they at least ought to find out something about what is going on there.

Some of us have been called upon to explain an epidemic of dying fish which occurred down there this summer, and since we do not know what is good for the fish in those waters we cannot very well tell what is harmful to them. So there is now a real interest in the establishment of a scientific laboratory of some sort on the Gulf Coast. I have been down there with Dr. Lund for the University of Texas, and as we could not find any place in which to do our chemical and biological work we put up a little laboratory of our own and really hope to accomplish something.

I am not exactly satisfied in my own mind as to just what the function of the Division of Aquatic Biology and Physics is. In the past we have had reports as to what has been going on during the current year, but to me that seems to be a waste of time and of printing. We have also had reports emphasizing the need of certain investigations, but the need of many investigations is so obvious that it is not necessary to talk about them.

It occurred to me that a good idea would be to have the person in charge of this division write a critique of the papers in the last volume of the Transactions. There are always some things in there that have not been thoroughly checked and might lead to error. I am interested particularly in two papers that were presented last year. In a paper I presented I had some data on the effect of a nominal amount of fertilizer in the pond on the oxygen supply and said it was not anything serious. Another paper also dealt with the effect of fertilizer

on oxygen supply and cautioned against the danger because the author found that in his 250 c.c. capacity containers the oxygen was completely exhausted when he added the amount of fertilizer that he did. However, he failed to make one calculation—and this is not an effort in the way of destructive criticism: it is merely bringing the matter to your attention—he did not stop to calculate that where he had that condition he was fertilizing a pond at the rate of about thirty to thirty-two tons of organic fertilizer per acre. As a matter of fact in actual fish cultural operations you never have anything of that sort; I do not believe there are very many fish hatcheries that could afford to buy sufficient fertilizer to fertilize at that rate.

It is such things as these which it might be a good idea to review and analyze in the papers of the preceding year. It might save other people the trouble of writing papers on the same subjects.

There is one other suggestion. Organizations such as the American Petroleum Institute, the Pharmaceutical Society and others have a research committee which assigns certain research to certain laboratories because they are particularly suited to the work both on account of their equipment and their personnel. I do not know whether instead of having a Vice-President of Aquatic Biology and Physics this Society might not better have a research committee which would do this same thing—see what ought to be done most urgently and assign it to the proper agency, either in the state or the federal government.

REPORT OF THE VICE-PRESIDENT OF THE DIVISION OF PROTECTION AND LEGISLATION

Guy Amsler

Some weeks ago one of our gracious fellow members, Mr. Talbott Denmead, summarized legislation enacted during the past year very thoroughly for me. I am greatly indebted to Mr. Denmead for the report which he gave me, and which is now presented for your consideration.

While 44 legislatures were in session the past year, it appears from the information assembled that approximately 30 enacted some form of game-fish legislation, and I am enclosing, as an appendix to this report, a chart which will give you at a glance a rather comprehensive picture of the situation, and illustrates the success of the game-fish legislative program for 1935.

Tennessee was the first state to reorganize its Department of Game and Fish, creating in its place a Board of Game and Fish Conservation Commissioners, consisting of 5 members, very similar in organization to the Model Game and Fish Commission suggested by the Committee of the International Association of Game, Fish and Conservation Commissioners, appointed to make a study of the 48 state fish and game agencies. Florida, Maryland, New Hampshire and South Carolina were among the states to make such changes in their administrative bodies, exercising jurisdiction over game and fish, while Rhode Island did away with its Commission of Inland Fisheries, and created in its place a Department of Agriculture and Conservation. Others attempted to reorganize their conservation bodies politic, and while the plan failed in several states, the

effort was well expended for it paved the way for success in the future. Several of the more important executive positions in approximately 14 states were vacated during the past year, either because of death, reorganization, or other reasons, and new appointments were made to either the old vacancy or the newly designated position.

The Arkansas Commission, under Act 323, was given Blanket authority to make rules and regulations governing seasons, methods, limits, etc. The Kansas Fish and Game Commission was given authority to regulate seasons. Utah also granted its Fish and Game Commissioner broader powers. West Virginia made a small appropriation available out of its general fund for conservation work. A bill was passed in Montana giving the Fish and Game Commission full control over seasons. Delaware extended the closed season on black bass. Kansas adopted a closed season of 1 month on these game fish. Tennessee established a closed season on Reelfoot Lake on black bass, and Washington by regulation provided greater protection for the black bass during the spawning period. Changes were made in the trout season in Michigan and Oregon, and Michigan abolished the closed season on white bass, effective January 1, 1935. California changed the open season on crappie from May 1-November 30th, and authorized the taking of them at any time in District 4¾ and Clear Lake. It also extended the open season on sunfish. New York shortened the statewide open season on lake trout. Nevada reallocated its districts and seasons.

The state of Indiana added to its Conservation Code over 20 laws enacted by the legislature during 1935. Among the changes made in gamefish laws was the reduction of the size limit on black bass to 10 inches. South Dakota placed a 6-inch limit on trout and prohibits the use of live carp as bait. Tennessee changed the daily and size limits on black bass taken from Reelfoot Lake. Washington by regulation raised the 6-inch limit on black bass to 10 inches. New York changed the limit on lake trout reducing it to three, excepting Lakes Erie and Ontario, where there is neither bag limit nor closed season. The Pennsylvania Commission under its authority reduced the bag limit on trout to 15 and possession to 15 of the combined species.

Arizona raised the "Class A" General Hunting and Fishing license fee to $3.50, and its Resident Fishing license fee to $1.75. Delaware raised its non-resident angler's license from $5.00 to $7.50, but permits ladies accompanying the angler to fish without charge. It also placed on its statute books a 6-day tourist license costing $3.25. Florida reduced its non-resident license fee to $5.00 and provided a 3-day tourist license costing $1.50. A $5.50 non-resident license must be obtained by the non-resident in Georgia's fresh or salt water. The Indiana legislature authorized a 10-day tourist license costing $1.00. Louisiana's $1.00 resident license, which applies to salt water as well as fresh, did not become effective until January 1, 1935. Maine raised the age limit junior licensees to 18, the cost of the resident license from 65 cents to $1.15, and the resident combination hunting and fishing license fee from $1.15 to $2.15. Tennessee has a special license on Reelfoot Lake, good for 5 days, costing $1.00. Montana adopted the 15-day license costing $1.50, and Nevada issues a free license to those over 60. Oregon has a juvenile license costing $1.00 and a tourist license tor 2 days costing $1.00. Vermont has a special license on Lakes

Bomoseen and St. Catharine for 14 days costing $2.15. South Dakota has a 5-day license costing $1.00. North Carolina's daily non-resident angling permit was raised in price to $1.10. Oklahoma requires all persons between the ages of 16 and 60 to have an angler's license regardless of bait used, and upon application a free permit will be issued to those over 60 to hunt and fish in the county of applicant's residence.

In the matter of prohibitting the sale of black bass regardless of where taken, there was introduced in the Indiana legislature the first day of the session a bill to accomplish that purpose. This bill was enacted into law. Florida and Delaware also joined the ranks of states absolutely prohibiting the sale of black bass, while Tennessee passed a new law relative to Reelfoot Lake, limiting the sale of black bass by commercial fishermen to 12 a day from those waters. New York passed a law prohibiting the sale of muskellunge regardless of where taken, and lake trout from all the waters of the state except Lakes Erie and Ontario. A law was passed in California prohibiting the sale of striped bass.

Some of the miscellaneous laws enacted the past year are:

Indiana—To maintain the flow and level of waters in dam areas; to prohibit the dynamiting of fish; to control pollution.

Florida—License and closed season on frogs.

New York—Anglers exempted from license requirements fishing in the Marine district of that state.

New Jersey—Passed concurrent laws with Pennsylvania further protecting game-fish.

This appears to be all the new laws and regulations that have been brought to my attention up to the present time, but there undoubtedly are more which will reach me later on and I will be glad to pass them on to you as they come in.

Following is a Game-Fish Legislative Progress Chart for 1935:

Tabulation showing states that have made changes during 1935 in their laws or regulations relative to licenses, seasons, limits, sale status of game-fish, and those having adopted the commission form of administration for their conservation agencies; those increasing the powers of their commissions, and miscellaneous items of interest to the conservationist.

Commission Established	Broadened Powers	Licenses[1]	Tourist Licenses	Seasons	Limits	Sales
Alabama	Arkansas	Arizona	Vermont[3]	Arkansas	California	Alabama
Florida	Kansas	Delaware	Delaware	Delaware	Indiana	Delaware
Maryland	Montana	Florida	Florida	Kansas	Missouri	Florida
N. Hampshire	Utah	Georgia[4]	Indiana	Michigan	New York	Indiana
Rhode Island		Indiana	Montana	New York	Oregon	Tennessee[2]
S. Carolina		Louisiana[5]	Oregon	S. Carolina	Pennsylvania	New York
Tennessee		Maine	S. Dakota	Tennessee[2]	S. Dakota	
		Nevada	Tennessee[2]	Utah	Tennessee[2]	
		New York	Pennsylvania	Washington	Washington	
		N. Carolina				
		Oklahoma				
		Wyoming				

[1]Under title "Licenses" states that have made changes in the resident and non-resident license fees.

[2]Applies to Reelfoot Lake only.

[3]Lakes Bomoseen and St. Catharine.

[4]Required for both fresh and salt water angling.

[5]Resident license provided by 1934 legislature but did not become effective until January 1, 1935.

Miscellaneous

Indiana passed laws to eradicate pollution and maintain water levels in dam areas—over 20 laws were passed during 1935 in the interests of conservation. *New Jersey* enacted concurrent laws with Pennsylvania further protecting game-fiish. *New York*—no license required to fish in the Marine District of that state. *West Virginia* made a small appropriation out of the general fund for game-fish work. *Michigan* abolished the closed season on white bass effective January 1, 1936. *South Dakota* prohibited the use of live carp as bait.

REPORT OF DIVISION OF ANGLING

Talbott Denmead

There is no mystery connected with the fact that there are about 9,000,000 persons who love to fish with hook and line; fishing takes you places; it exercises you physically and mentally; it soothes you spiritually. It would be a good thing for the American Fisheries Society if more of its members went fishing oftener and if its anglers would study their angling scientifically. Let's all get together on this subject.

The three questions most frequently propounded to the vice-president of your Division on Angling, by letter, telephone, and personal calls, are: How? When? and Where? to fish.

To the first question I would say fish in whatever manner it suits you best, within the limits of the fish laws and good sportsmanship; the dry fly angler, the bait caster, the deep sea fisherman, and the boy (young or old) who goes after bluegills or horned pout are all brothers under the skin.

To the second question "When to fish," the answer is easy—fish when it suits you, when you need recreation, and as often as possible. If you do this, some day it will suit the whims, the pleasures, or the fancies of the fish to strike—and you will be there and so piscatorial history will be made.

But the answer to the third question "Where to fish?" is not so simple. Perhaps as good an answer as any would be, "Seek and ye shall find," but that would not satisfy the inquirer who asks, "Where can I go tomorrow, not far away, and catch my limit of black bass?" My reply to this, or similar questions, is "My friend, if I knew I would be there myself instead of here in this hot office answering questions."

Perhaps someone had just asked Sir Izaak Walton *How, When and Where* to fish when he said "Angling is somewhat like poetry, men are to be born so: I mean with inclinations to it; * * * * he that hopes to be a good angler must not only bring an inquiring, searching, observing wit, but he must bring a large measure of hope and patience, and a love and propensity to the *art* itself."

The following items will give you some general ideas concerning angling in 1935:

1. Reports of increases in black bass the past spring and summer have been received from a majority of the 112 deputy black bass law inspectors. The drought is over and the bass are coming back.

2. More angling has been done by the people than for the past several years. Though the number of licenses issued have been on the decrease since 1932 to the present year, the states are reporting increased sales for 1935. There are several reasons, among which may be mentioned the stricter hunting regulations and shorter hunting seasons, while the angler may fish every month of the year.

3. There has been an increased interest in salt-water fishing recently. This is due in part to fewer fishing restrictions on the angler in coastal waters. There are, generally speaking, no seasons, limits, or licenses for the Atlantic Ocean and the adjoining tidal bays. Also, the discovery of game fish off the north Atlantic Coast, the presence of which was not known to anglers formerly.

4. A great number of wet-fly artists are becoming dry-fly enthusiasts now. More live-bait casters are taking to artificial baits, and the fly rod for black bass is getting more popular. Pan fish—crappie, bluegills, and perch—are being taken on light fly rods also, instead of heavy tackle affording 100 per cent more sport.

5. This year was a banner year for promulgating part-time or tourists angler licenses, good for a short period at a reasonable price. Twenty states have adopted this form of license, advocated by the U. S. Bureau of Fisheries, during the past two years. The total is now twenty-eight.

6. Pollution, like the poor, is always with us, and I am skipping it. Also, the subject of fish laws for these subjects will be ably handled by others. I cannot pass the subject of laws, however, without calling your especial attention to the progress made by Florida in 1935. It adopted a Commission form of conservation government along the lines recommended by the Hawes Committee of the International Association of Game and Fish Commissioners; it adopted a part-time tourists angler's license; and, last but not least, it prohibited the sale of black bass from all the waters of the state at all times.

7. I think artificial baits of all sorts and descriptions are being more generally used than formerly. This is good, for there is a lot of valuable fish food destroyed and wasted by anglers in catching and using forage fish and other forms of living things for bait. Also, more small fish are killed in using bait than with the artificials equipped with a single hook.

8. The increased cost of fish food the past year hurts the angler. It takes more angler's money to raise less fish.

9. More interest has been displayed by sportsmen in 1935 in organizations than for several years. Several states have formed Federations of Sportsmen Associations, notably Tennessee and New Jersey. The Izaak Walton League has organized many new chapters and added many new members this past twelve months. Recently the new American Wildlife Institute was organized to help further the movement. In unity there is strength! We will have better fish laws and greater observance thereof when the sportsmen are better organized.

10. Permit me to compliment the State of Oklahoma on a more strict enforcement of its law prohibiting the sale of black bass. When the Federal black bass law was amended in 1930 and the Bureau of Fisheries was charged with its enforcement, black bass were being unlawfully shipped in and sold in Oklahoma, openly. Today I am told it is difficult to purchase black bass in the state. So far as the Bureau knows no black bass have been shipped into Oklahoma in any quantity since Florida prohibited the sale on export of these game fish.

In closing I want to say a word to the state fish and game authorities attending this Convention. The Bureau of Fisheries prepares, every two years, a circular containing a summary of the game-fish laws. Many state authorities now have power to promulgate regulations changing seasons, limits, etc., and they exercise the power conferred on them frequently, but I regret to say they do not notify the Bureau of Fisheries of the changes which they promulgate. I plead with you for our mutual benefit. Make a note to notify the Bureau of Fisheries of changes in your fish laws when they are made. Don't let us find it out accidentally six months later.

Discussion

Mr. Denmead: Mr. LeCompte requests me to add to the list of legislative matters which have arisen during the year, referred to in the report of Mr. Amsler, just read, the fact that Maryland passed a law which gave its commission discretionary powers in the matter of changing or regulating seasons.

Mr. I. T. Quinn (Alabama): Supplementing the Amsler report and that of Mr. Denmead, I may say that since these reports were filed Alabama has adopted the commission form of conservation administration. Heretofore, as most of you know, the commissioner has been elected every six years by popular vote, the same as other state officials. At the present session of the legislature, just a few days ago, the commission form was adopted, setting up a state conservation board appointed by the governor, and what was the Department of Game and Fisheries is now known as the Department of Conservation of Game, Fish and Sea Foods. The commissioner is appointed for a term of four years. The conservation board is given complete regulatory powers to fix open seasons and bag limits on all game and creel limits on fish. In addition to this, for several years, we have prohibited the sale of bass taken from the public waters of the state of Alabama. Last week a bill passed in the House of Representatives of the state, which is now in session, prohibiting the sale of bass at all times, regardless of where taken. It is expected that that bill will be enacted into law by receiving the approval of the governor before the end of this week.

The President: I might also add that at the last session of our legislature our Conservation Council was given blanket authority to make fish and game regulations in Ohio, with the exception of the commercial fishing of Lake Erie.

APPOINTMENT OF COMMITTEES

Auditing—Messrs. Talbott Denmead, Fred Westerman, W. W. Aitken.

Nominations—Messrs. Fred Foster, Thaddeus Surber, William J. Tucker, Walter Chute, D. N. Grim.

Time and Place—Messrs. I. T. Quinn, Leonard P. Schultz, C. E. Sykes, J. A. Rodd, George Stobie.

Resolutions—Messrs. John A. Van Oosten, S. B. Locke, Arthur L. Clark, E. Lee LeCompte, A. H. Wiebe.

Program—Messrs. Herbert S. Davis, A. D. Aldrich, Carl L. Hubbs.

Publicity—Messrs. Robert Chandler, Robert M. Jones, L. D. Rickey.

Publications—Messrs. A. B. Cook, Jr., Eugene Surber, B. W. Taylor, T. H. Langlois, W. W. Aitken.

REPORT OF COMMITTEES

AUDITING COMMITTEE

MR. DENMEAD: Your Auditing Committee has checked the books of the secretary-treasurer, also the accompanying vouchers, for the fiscal year ending June 30, 1935, and finds the report as submitted to be correct.

I personally accompanied the secretary-treasurer to the vaults of the Riggs National Bank in Washington, D. C., within the past two weeks and aided him in checking the permanent funds securities of the Society, and the report submitted to this annual meeting of the Society relative thereto checks with my inspection.

Your committee recommends that the total appropriations for clerical and stenographic services for the year 1935-1936, exclusive of expenses in connection with the preparation, proof-reading and indexing of the Transactions, be the same amount as last year, namely, $350.00.

(The report of the committee was approved.)

COMMITTEE ON RESOLUTIONS

The Committee on Resolutions presented the following report, which was unanimously adopted:

Appreciation of Courtesies

WHEREAS, This sixty-fifth annual meeting of the American Fisheries Society is about to adjourn; now

BE IT RESOLVED, That the American Fisheries Society at its sixty-fifth annual convention assembled in Tulsa, Oklahoma, September 11, 1935, hereby expresses its sincere appreciation of the fine hospitality and many courtesies extended to its members and guests during the convention by the Oklahoma Game and Fish Commission, the officials of the City of Tulsa, the Tulsa Chamber of Commerce, the managements of the Mayo Hotel, the Southern Hill Country Club, the Tulsa Country Club, the Tulsa *World*, the Tulsa *Tribune*, broadcasting stations KVOO and KTUL, Mr. H. V. Foster, Mr. Frank Phillips, Mrs. Van H. Montgomery, Mrs. John G. Catlett, Mrs. J. C. Denton, Mr. Robert Chandler, Mr. R. M. (Bob) Jones, Conventions Secretary, and the other organizations and individuals who have made the conference so successful, enjoyable, and profitable.

Water Purity Standards

WHEREAS, Stream pollution is now receiving important consideration by both federal and state authorities; and,

WHEREAS, precedents and standards about to be established for the regulation and abatement of pollution by these authorities will have far-reaching effects on the future of both food and game fisheries; and,

WHEREAS, Conditions resulting from the treatment or partial removal of pollution in many cases may meet the requirements of other interests, but still leave these public waters unsuited for fish; therefore,

Be It Resolved, By the American Fisheries Society, that, in the framing of legislation now pending or contemplated, and in the drafting of recommendations by federal and state agencies relative to water purity standards to be met or maintained in public waters, correct standards require conditions not merely sublethal, but favorable to all stages of the desirable food and game fishes of the particular region, and to those aquatic organisms, both plant and animal, which comprise the food and food chains of these fishes; i. e., that, in such public waters as may reasonably be expected to support desirable fishes, the limitation or treatment of pollution merely to produce those barely sublethal conditions under which some species of fish can exist, even though the water be rendered useable for industry or potable for man, does not constitute the establishment of a suitable or satisfactory environment for desirable food and game fishes.

American Wildlife Institute

Whereas, The American Wildlife Institute was recently organized to serve as a cooperative and coordinating agency for all North American groups interested in the restoration of fish, game, and other wildlife; and

Whereas, Such a central agency can be of great assistance to the work of the American Fisheries Society and its members;

Therefore, Be It Resolved, That the American Fisheries pledges its hearty cooperation to the American Wildlife Institute and hereby authorizes its officials to enroll the Society as one of the organizations affiliated with the Institute, if they deem it advisable.

SPECIAL COMMITTEE ON REVISION OF BY-LAWS

The Special Committee on Revision of By-Laws, appointed last year, T. H. Langlois of Ohio, Chairman, made an extensive report, and the changes recommended were adopted, with a few minor changes. The By-Laws as amended appear in full on page 406.

COMMITTEE ON TIME AND PLACE

Mr. I. T. Quinn: Mr. Chairman, I believe the American Fisheries Society and the International Association of Game, Fish and Conservation Commissioners had more invitation from cities throughout the country this year than ever before. More representatives personally appeared before the committee than ever before, extending cordial invitations to the two organizations to hold their conference next year in the communities for which these representatives respectively appeared. In coming to a decision as to the place of meeting for next year we had to take into consideration the areas in which the meetings had previously been held. The committee went back to the early history of the American Fisheries Society and noted the places in which the annual conferences had been held down to the present. The decision was a difficult one. There are two things the committee believed to be important in the holding of conventions of this kind. One was the amount of service that the convention could render to the area in which the meetings were held; the other was the assistance the So-

ciety could receive in those communities in the object it has in view. The committee were in session about half a day, and when the final vote was cast the decision was that the first week in September, 1936, would be the best time to hold the two conferences, and that the place should be Grand Rapids, Mich.

I move you, Mr. Chairman, that the report of the committee be received and approved.

Mr. Regan: I second the motion.

(The motion was carried unanimously.)

Mr. Westerman: Mr. President, I wish to convey to the Society through you the thanks of the Michigan Conservation Department and of the Michigan members of the society who are here for your acceptance of Michigan's invitation to entertain you at Grand Rapids in 1936. We believe we have much to show you in Michigan that you are all interested in. I am not going to make any extended remarks; there are too many other good things on the program and too many interesting things to be seen in the splendid setting in which we find ourselves today. We hope to see you all in Grand Rapids in 1936. (Applause.)

The Secretary: The meetings will actually start on August 31st and continue on September 1, 2, 3 and 4. The International Association will meet on August 31st and September 1st, and the American Fisheries Society on September 2nd to 4th.

COMMITTEE ON NOMINATIONS

Mr. Foster: Mr. Chairman, the Nominations Committee has been confronted with an unusually difficult task. In addition to the arduous duties of distributing recommendations for officers and committee members among the various groups, such as executives, fish culturists, and scientists, we have also been confronted with a change in the By-Laws which eliminates two committees; therefore I trust that the members here will bear with us in our efforts to recommend a desirable slate. Certain of the older members have insisted on being dropped from some of the committees, and some of the newer members have not been given the recognition they deserve, due to the same cause.

Your Nominating Committee submits the following for officers, vice-presidents of divisions and committee members for the ensuing year:

Officers

President—Frank T. Bell, Washington, D. C.
1st Vice-President—A G. Huntsman, Toronto, Canada.
2nd Vice-President—I. T. Quinn, Montgomery, Alabama.
Secretary-Treasurer—Seth Gordon, Washington, D. C.
Librarian—Eben W. Cobb, Hartford, Connecticut.

Vice-Presidents of Divisions

Fish Culture—T. H. Langlois, Columbus, Ohio.
Aquatic Biology and Physics—A. S. Hazzard, Ann Arbor, Michigan.
Commercial Fishing—R. H. Fiedler, Washington, D. C.
Protection and Legislation—Carl D. Shoemaker, Washington, D. C.
Angling—S. B. Locke, Chicago, Illinois.

Committee on Foreign Relations

W. F. Thompson, *Chairman*, Seattle, Washington.
James A. Rodd, Ottawa, Canada.
W. A. Clemens, Nanaimo, B. C., Canada.
Herbert C. Davis, San Francisco, Calif.
Fred J. Foster, Seattle, Washington.
Thaddeus Surber, St. Paul, Minnesota.
Fred A. Westerman, Lansing, Michigan.

Committee on Common and Scientific Names of Fishes

Carl L. Hubbs, *Chairman*, Ann Arbor, Michigan.
Samuel F. Hildebrand, Washington, D. C.
Wm. J. K. Harkness, Toronto, Canada.
John O. Snyder, Stanford University, California.
Walter H. Chute, Chicago, Illinois.
A. H. Leim, St. Andrews, N. B., Canada.

(The report of the Committee was unanimously adopted and the nominees were elected by acclamation.)

THE RETIRING PRESIDENT: I will ask Mr. Denmead and Mr. Higgins to escort the newly elected President to the chair.

Mr. Bell was escorted to the chair.

THE RETIRING PRESIDENT: Members of the American Fisheries Society, I want to present to you our new President, Frank T. Bell, United States Commissioner of Fisheries.

THE PRESIDENT-ELECT: Members of the American Fisheries Society, in accepting this office I want you to realize I do so with a full sense of my limited abilities, but I hope to make up for the lack of ability in enthusiasm and in the desire to promote the interests of the Society. I am going to inform the other officers that they will probably have a little more work to do this year than they have had in the past, to make up for my shortcomings. I appreciate the high honor which you have conferred upon me, an honor I appreciate all the more because it is received in Oklahoma, the state in which I practically grew up until I was twenty-two. I thank you very sincerely.

THE RETIRING PRESIDENT: I wish to thank each and every member for the splendid cooperation I have received during the past year. I am confident that Mr. Bell, your new President, will in the ensuing year maintain the high ideals of this organization. If there is no further business the meeting will stand adjourned until the 2nd of September, 1936, at Grand Rapids, Michigan.

Whereupon the Sixty-Fifth Annual Meeting of the American Fisheries Society was adjourned.

In Memoriam

H. Nelson Emmons, Massachusetts

D. F. Fesler, Illinois

Louis C. Hirsheimer, Wisconsin

Carol J. Hyland, Michigan

Winthrop Parker, New Hampshire

J. L. Phillips, Texas

George D. Pratt, New York

J. J. Schrank, Ohio

C. B. Spears, New York

Francis H. Sumner, California

Julian S. Wooster, New York

(This list includes those members whose deaths have been reported since the last Annual Meeting.)

EDITOR'S NOTE—The editor is pleased to report that through an error the name of Guy Cary, New York (Life Member), was included in the list of deceased members published in the 1934 Transactions.

PART II
PAPERS AND DISCUSSION

THE NEED FOR INVESTIGATING FISH CONDITIONS IN WINTER

CARL L. HUBBS AND MILTON B. TRAUTMAN
Institute for Fisheries Research, University of Michigan, Ann Arbor, Michigan

This paper applies primarily to those regions where ice covers most standing waters for a considerable period. The purpose of the paper is to emphasize the need for investigating freshwater fish conditions in winter to the end that the annual fish crop may be increased. This line of fisheries investigation, though often recognized as a need, has seldom been carried out.

I.

An analysis of the need for winter investigations and of the part these should play in fisheries work, calls for a review and interpretation of inland fisheries research during the past fifteen years. Fisheries studies throughout this period have been connected with the four primary means of increasing the fish crop, namely: (1) stocking hatchery-reared fish, or introducing exotic species; (2) protecting the natural brood stock reserve by the enactment of laws restricting the taking of fish, and by the enforcement of these laws; (3) preventing waters from becoming (or remaining) unsuited, through pollution, to the desired food and game fishes; (4) creating more favorable conditions for the support of these valued forms of fish life.

During these past fifteen years, as in many previous periods, the propagation and distribution of fish have been made more efficient by application of scientific principles, and the various fish species are being planted in ever increasing numbers. The definite trend away from the planting of fry and small fingerlings, toward the stocking of larger fingerlings, half-grown and even adult fish, has been in general validated and in part prompted by pertinent investigations (unfortunately too few). Sustaining the yield of game fishes, where the species already occur, and establishing species where they are absent, has been placed on a more effective and economical basis by numerous stream and lake surveys.

The continued efforts of the various states and the federal government to increase the protection of fishes from overfishing and from law violators have been aided, and in part suggested, by investigations of fish biology. These studies have shown what sort of protection is needed, and analyses of the catch have tested the effectiveness or failure of various restrictive measures now in force or contemplated.

The real progress made during the last fifteen years in lessening the harmful pollution of natural waters has been greatly assisted by re-

search. The amount of harm done to fish life, and to other aquatic resources and recreational values, has often been determined. The whole difficult problem has been clarified by showing that after proper treatment, sewage of certain types is not only harmless, but actually beneficial to fish life. The multiple effects of toxic wastes on fishes have frequently been indicated in field and laboratory studies. The treatment of wastes to destroy their toxicity has been made possible by the researches of chemical engineers and by fishery investigators, who have determined the toxicity threshold of the wastes.

The organization of the newest field of fishery work, stream and lake improvement, has been a direct outcome of stream and lake surveys. Repeated indications of poor production of food and game fish in certain streams and lakes, or in certain sections thereof, naturally led to the search for remedial measures. Ecological observations of general conditions prevailing where fish abound, and of the specific environmental features providing good shelter, abundant food and suitable spawning conditions, called to mind that these obviously favorable conditions were often lacking or inadequately present in the waters yielding a poor fish crop. Preliminary experimental improvement work indicated the practicability of supplying these lacking or deficient conditions and increasing the fish production through this form of modification of the physical features of the environment.

Studies of hydraulics and engineering principles have aided in developing long-lasting and efficient improvement devices. Careful records have shown that the physical environment has been improved, for example, by digging out holes in the stream bed. Biological tests have indicated that shelter, spawning and food conditions have all been bettered in both streams and lakes, and that fish production can be increased well toward the limit imposed by the basic fertility of the water. Expectations that even this natural limitation to fish production may be overcome are based chiefly on the long-continued and extensive scientific investigations by Birge and Juday on the biological productivity of Wisconsin lakes, and on the possibilities of increasing the natural fish crop through fertilization of the water. Additional research is required to determine the amount of benefit obtainable from the use of the various methods of lake and stream improvement, and it is particularly in this new field that winter investigations are needed.

II.

In reviewing inland fishery research over the past 15 year period, we note that the investigations have been confined almost wholly to the warmer months. The investigators who have busied themselves with field work in summers have come indoors over the winter, to carry on laboratory work in fisheries, to write up the results of their summer field work or to engage in teaching or some other line of work not directly connected with the fisheries.

Almost no real effort has been made to determine how seriously the

winter conditions in different waters affect fall or winter plantings of fry, fingerlings or adults, or how unfit these waters are rendered by unfavorable winter conditions for each game fish species. A bare beginning has been made in determining the mortality in trout eggs and alevins in the gravel over winter. Until such studies are completed, it will be impossible to compare intelligently the effects of artificial and natural reproduction, or to determine the relative advantages of planting fish the previous fall or during the fishing season. Learning where fingerling fish naturally live during the winter should aid in selecting effective sites for winter plantings.

Only during the last three or four years has any considerable effort been made to determine the amount of depletion suffered by the game fishes through winter fishing. Local residents and resorters have grown hot, with arguments as to the proportion of pike caught through the ice, yet little effort has been made to get at the facts. In another talk on this program, Mr. Eschmeyer discusses the complete creel censuses being taken in winter as well as summer in some Michigan lakes. The survival ratios and change in weight of fishes over winter, vital to the determination of the most satisfactory open seasons, have remained largely undetermined.

Wise and effective regulations for the control of certain predators can hardly be enacted without knowledge of their winter activities. Animals not often considered predators may prove destructive in winter, for example, ciscoes, which in summer subsist on plankton or on minute bottom organisms in deep water, in winter feed to a large but not accurately determined degree on young bluegills. Mergansers are suspected of being the most serious winter predators in many trout streams, especially during severe winters when the freezing of the Great Lakes drives these fish-eating birds into the open trout streams. Some evidence suggests that these ducks may be a prime factor in depleting the trout supply, but the whole problem needs a more critical and extensive investigation, to determine not only the extent of harm done but also the most effective means for controlling the predation, should the need for control be indicated. To avoid a controversy, mention may be made of the undetermined loss of trout or of trout food down the gullets of otters, which feed all winter.

With some commendable exceptions, pollution surveys have been confined to the warmer seasons, even though conditions may become worse under the ice than in open waters. This condition often holds true even when the sewage involved is not discharged in winter, for sludge accumulated on the bottom, from the discharges of summer and fall, as from sugar plants, continues to decompose over winter. What may be termed natural pollution, in waters unusually rich in organic matter, also tends to be most destructive in winter, but the effects, even when extreme enough to cause "winter kill," have ordinarily passed by without investigation. The mortality that takes place under the ice or along with the spring breakup, may remove many

more fish than are planted in a lake. Determinations of the cause of death, whether lack of oxygen, accumulation of toxic substances, disease, or starvation should lead eventually to means for avoiding or compensating for such losses.

The investigations, surveys and even casual examinations, on which stream and lake improvement work have been based, have generally been conducted solely during the warmer months. Recent observations in Michigan have strongly confirmed our previous supposition that such field researches should be extended to include the winter months. Particular needs for winter field work in connection with lake and stream improvement, that have thus been brought to our attention, may be emphasized in query form:

May not mapping, sounding and determination of bottom soils of inland waters be most efficiently done on or through the ice?

Do the weed beds remain in thick enough stands over winter to provide adequate shelter for young and half-grown game fish?

Are brush shelters attractive to fish in winter, as well as in summer?

Where should shelters be installed to provide effective cover in winter?

Does a serious food shortage arise in winter? (Trout, pike, pike perch, perch and other fishes feed more or less actively over the winter.)

If such shortage exists, is there any practicable means of supplying the deficiency?

How seriously does the ice harm improvement devices?

Does the surface ice, which forms in quantity in most trout streams in subzero weather, lift up deflectors and covers?

How can the improvement devices be constructed to prevent loss or harm by ice action?

Does the ice-shove in lakes destroy or displace shallow-water weed beds, shelters, spawning beds, minnow spawning slabs?

How extensively does the anchor ice, which forms freely on the bottom of trout streams in very cold periods, carry off gravel from good spawning beds?

How much trout food is destroyed by this action of anchor ice?

Does much harm (or good) result from the gouging of the stream bed by upturned cakes of ice?

What effect on newly hatched trout fry, and on the older fish, and on fish food, has the moving along of masses of ice that almost fill the stream? The forming of ice jams and the subsequent scouring of the stream beds by floods?

To what extent are ice jams (likewise log jams) produced by stream improvement devices which constrict the current?

May not the ice have a more serious effect on the trout than low water stages and high summer temperatures?

Do current-speeding stream improvement devices, such as deflectors, retard or increase the formation of anchor ice?

Do deflectors, dams and covers increase the formation of surface ice in their lee? If so, what effect does this have on the formation of anchor ice, and on the fish life?

Can harm to improvement devices in lakes be avoided by raising or lowering the water level over winter?

What other effects would the changed level have?

How seriously do smallmouth bass streams (for example) flood in winter?

What effect does the high water, with the speeding of the current and the shifting of the stream bottom, have on the semi-hibernating bass?

What practicable means can be devised to lessen the winter flooding?

Do fish work out of lakes in winter, or down streams, perhaps over dams which they can not again surmount, or upstream into spring feeders?

Is it desirable to provide conditions which will cause the fish to refrain from such movements?

If so, what sort of holes or shelters will prove effective in retarding the movements?

In any event, where and how may winter conditions in streams and lakes be made most conducive to the survival of the desired species over the winter?

III.

There are several obvious reasons why winter investigations in the field of fresh-water fisheries have been so seriously neglected. Foremost among these reasons perhaps have been those involved in the question of available personnel: the insufficient supply of trained fisheries investigators, and the availability, over their summer vacation of university and college instructors and graduate students, whose training or experience more or less thoroughly qualifies them as substitutes for full-time technical staff members. Related reasons are the apparent economy of employing the university men for summers only; or the lack of sufficient funds to engage a technical staff on full-time basis; the unwillingness of conservation officials to sacrifice fish funds from hatchery operations for research work at any time, or their failure to appreciate the importance of scientific work. Happily these blocks to fisheries research work in general are being broken down in the more progressive states.

Another important reason why the investigations have largely been confined to the summer is that most interested anglers see their favorite waters only in the warmer seasons, when such critical factors as low water, high temperatures and overfishing naturally impress them, and prompt them to call for investigations. Most research workers and conservation officials themselves have seen so few lakes and streams in mid-winter that they have scarcely appreciated the stress of winter conditions.

Finally, the discomfort of working in and about freezing water has retarded winter investigations. The usual rush to complete reports, correspondence and laboratory experiments has provided those workers free to engage in winter field work with a good excuse if not the necessity for remaining in warm offices or laboratories over the cold period.

To balance inland fishery research from a seasonal standpoint, it will be necessary for the appropriate authorities:

(1) To realize the importance of winter conditions as factors controlling the game fish crop;

(2) To build up a permanent, all-year staff of able and willing research workers, rather than to rely solely on university men free only in the summer;

(3) To employ a sufficient number of investigators, with adequate technical and clerical assistants, to permit at least one trained worker to spend much of his time each winter in field work.

It is concluded that there is a real need for the continuation and extension of fisheries research in inland water; and that winter investigations may be as important as summer studies, and that they have certainly been unduly and harmfully neglected; that personnel and facilities should be provided to permit the investigation of these winter conditions which limit, or may control, the annual game fish crop.

THE FOOD OF SOME BUCKEYE LAKE FISHES

Lela A. Ewers and M. W. Boesel
Cottey College, Nevada, Mo., and Miami University, Oxford, Ohio, respectively

The present study is one of a series undertaken by various workers under the direction of Mr. E. L. Wickliff, chief of the Bureau of Research of the Ohio Conservation Division. It has involved the dissection of 580 specimens belonging to 16 species. The fish were taken at twenty-four different stations in the lake. Crustaceans were identified by the senior author, and insects by the junior author.

The authors are indebted to Mr. E. L. Wickliff for suggestions and materials; to Dr. R. C. Osburn, director of the Frantz Theodore Stone Laboratory, for use of equipment; and to Mrs. M. W. Boesel for typing and other assistance.

SWEET SUCKER (See table I). On the basis of our table, the sweet sucker feeds to the extent of over 50% on Entomostraca and to a more limited extent on midge larvae and pupae. Fish under 37 mm. in this small series had eaten no insects, whereas those over 37mm. had all taken some. Our information is too limited however to draw sweeping conclusions.

CARP (See table II). Fish in our series had eaten 51.5% crustaceans, chiefly Cladocera, and 36.5% insects, all of which were larval or adult midges. Sibley (1929) found midge larvae constituting 52% of the diet in an 18 to 55 mm. series of 24 specimens; other items were crustaceans, 9% and plants, 14%. Forbes and Richardson (1908) record the carp as feeding chiefly on vegetable matter.

BLUNT-NOSED MINNOW (See table III). The food in the stomachs of all fish in this series was in very poor condition, consisting mainly of much fragmented remains of Cladocera. The most abundant organism was *Chydorus sphaericus.* A trace of algae was present. Kraatz (1928) made an extensive study of this species and reported it a very versatile feeder on plankton and bottom organisms.

GOLDEN SHINER (See table IV). In the size-range (23 to 40 mm.) studied, crustaceans constituted a greater part of the stomach contents than did insects. All of the Crustacea were Cladocera. It is interesting that the insects eaten were all adults that were probably taken at the water surface. Eggs made up an important portion of the diet. In general, the stomach contents were badly fragmented and considerable material had to be designated as debris. Nine of the golden shiners which were used for these studies were seined from

the open lake, and fourteen were taken near vegetation. Those taken from the open lake showed the following stomach contents: Crustacea, 59.44%; Insecta, 0.55%; unidentified eggs, 12.22%; and debris, 27.77%. Those taken near vegetation showed the following: Crusta cea, 20%; adult Insecta, 43.08%; unidentified eggs, 8.85%; and debris, 28.07%. These collections were made on succeeding days and it seems likely that the food habits of the fish vary much with the type of food available; it is reasonable to suppose that flying insects would be more numerous about emergent vegetation. In specimens from Lake Erie measuring from 15 to 49 mm. Crustacea (mainly Cladocera) were found to make up 78.8% and Insecta 7.2% of the food (Ewers, 1933). Sibley (1929) reported golden shiners of larger size than those here studied as eating algae, 53%; adult midges, 12%; caddis-worms, 8%; and Crustacea, 7%. Cassidy, Dobkin, and Wetzel (1930) found the golden shiner to feed almost entirely on plankton, especially Cladocera. Pearse (1915-16) found Entomostraca constituting about 76% of the diet and Forbes (1883) found 50% of the food to be plant material.

CHANNEL CAT (See table V). The only considerably evident remains were those of midge larvae and pupae. Our series is too small to give an adequate sample of the food of this species.

BLACK BULLHEAD (See table VI). According to our studies, the black bullhead feeds predominantly on crustaceans, or to the extent of 74.07%, with Cladocera and Copepoda about equally well represented on the basis of volume. *Chydorus sphaericus* was the most abundant species taken but *Cyclops americanus* was most important from the standpoint of bulk. Insects were present to the extent of 12.22%. All the insects found were Chironomidae, particularly larvae, but also pupae and adults. Pearse (1915-16) studied black bullheads from 35 to 280 mm. and in these fish, averaging 118.8 mm., he found 45.1% insects and 21.4% oligochaetes. It may be worth adding that in the case of the collections made at two stations on July 17, the volume percentage of Crustacea was 93.4 and 95.4%; whereas in the collections made at two other stations on August 5, the volume percentage of Crustacea was 63 and 60%. This is possibly suggestive of a seasonal change in the food habits of the black bullhead.

TADPOLE CATFISH (See table VII). A feature in the food of Buckeye Lake specimens of this species is *Hyalella knickerbockeri* which made up 31.67% of the stomach contents. Ostracods were also quite abundant. Crustaceans as a group made up 57.76% of the food and insects 15.76%, chiefly midge larvae and paupae. The stomach contents were broken up to such an extent that over 25% had to be listed as debris. A series of 14 tadpole catfish taken in vegetation had eaten Hyalella to the extent of 59.64%. Pearse (1915-16) reported a wide variety of food including oligochaetes, plants, insect larvae, amphipods, etc.

BROOK SILVERSIDE (See table VIII). The most abundant food organism found in this species was *Scapholeberis mucronata,* which made up 31.31% of the food. Crustacea averaged higher in volume than did Insecta. The insects taken were exceedingly varied in nature and were chiefly winged adults. Of these, adult midges were most important; thrips were also numerous. The brook silverside apparently does considerable surface-feeding. Pearse (1915-16) found over 50% of the food to be insects, chiefly adults. In another paper (1915) he records over 10% plant material. Forbes (1883) found no plant material with over 50% insects.

WHITE CRAPPIE (See table IX). Buckeye Lake specimens in the 15-60 mm. size-range were found to contain 91.19% crustaceans and 3.64% insects. Easily the most abundant single species of food organism was *Diaphanosoma leuchtenbergianum.* Cladocera in general were more abundantly present than were Copepoda. Although insects were found in about one-fifth of the stomachs they constituted only 3.64% of the diet and the only insects found were midges of various stages, particularly larvae. There seems to be little correlation between food of the white crappie and its size, place of capture, and season so far as our data will indicate. Lake Erie specimens (Ewers, 1933) are similar in food habits to those of Buckeye Lake in that crustaceans are predominant food organisms and insects taken are confined to Chironomidae, but Copepoda are more abundant than Cladocera. Sibley (1929) in larger specimens found fish the predominant food.

BLUEGILL (See table X). The bluegill in the 21-37 mm. range seems to feed largely on small Crustacea. Our studies show 86.21% Crustacea, about equally divided as to volume between Cladocera and Copepoda, and 13.23% Insecta, chiefly midge larvae. *Cyclops americanus* and *Sida crystallina* are important items of food. Every one of the 53 bluegills dissected contained some Cladocera. In specimens averaging 51.1 mm. Pearse (1915-16) found a considerably greater dependence on insects for food. Insects constituted 46.2% of the diet as compared with 24.9% for Crustacea.

COMMON SUNFISH (See table XI). The predominant food species found in our specimens were *Hyalella knickerbockeri* (31.15%) and *Ceriodaphnia reticulata* (29.29%). Cladocera, constituting 43.61% of the food, were found in each of the stomachs. Midge larvae were present to the extent of 10.15%. In larger specimens (25-80 mm.) Sibley (1929) found midge larvae making up 40% of the food. Pearse (1915-16) in 116-187 mm. specimens found snails and plant material each constituting over 25%.

LARGEMOUTH BASS (See table XII). Since the size-range of the fish examined is rather great, it was thought advisable to divide the series into three groups, with results as follows: 87 fish in the

21-50.5 mm. range had eaten 69.7% crustaceans, 27.0% insects, and 1.4% fish; 20 fish in the 51-80.5 mm. range had eaten 29.1% crustaceans, 66.2% insects, and 4.8% fish; and 4 fish in the 81-112 mm. range had eaten no crustaceans, 11.5% insects, and 88.5% fish. It is clear that there is a progressive shift from crustaceans to insects and finally to fish. Cladocera were much more prominent than Copepoda in the diet, the most evident being *Sida crystallina, Scapholeberis mucronata* and *Ceriodaphnia reticulata.* Hyalella knickerbockeri made up 18.24% of the diet. Insects were highly varied but aquatic forms were distinctly predominant. Damselfly nymphs and water boatmen were especially conspicuous. There is evidence of some surface feeding. Data collected from 29-83 mm. Lake Erie specimens (Ewers, 1933) showed 87.1% crustaceans with both copepods and cladocerans well represented, only 1.38% insects and 11.4% fish. It should be noted that other workers (Forbes, 1903; Deryke and Scott, 1922; and Turner and Kraatz, 1930) have found a rather definite progressive change in the food habits of this species.

YELLOW PERCH (See table XIII). The table attests the importance of crustaceans in the diet of the yellow perch, both copepods and cladomerans being well represented. *Cyclops americanus* was a very prominent species, forming 12.22% of the food by volume. *Hyalella knickerbockeri* made up 18.54% of the food. Of the insects, midge larvae were most important but a variety of other aquatic insects were present. The fish dissected were taken at five different stations in Buckeye Lake. It is interesting to observe that only one of the five stations was in vegetation and that only in the group of fish taken at that station did the insects constitute more than 50% of the diet; in fact, the insects made up 66.22% as compared with 24.85% for crustaceans. In Lake Erie specimens (Ewers, 1933), Crustacea, especially Copepoda, made up over 94% of the food. Sibley (1929) found Cladocera present to the extent of 45%; Copepoda 40%. Turner (1920) concluded that the diet of the perch changes from copepods to cladocerans, copepods, and midge larvae; larger organisms are later added and snails and crayfish are finally included.

LOG PERCH (See table XIV). Crustacea formed 67.87% of the diet of specimens examined. These were chiefly Cladocera, especially *Sida crystallina* and *Ceriodaphnia reticulata.* Insects, which were almost altogether midge larvae and pupae, made up 30.70%. Turner (1921) found Entomostraca becoming a less important article of diet with the growth of the fish.

WHITE BASS (See table XV). Buckeye Lake white bass in the 54-96 mm. range was found to feed largely on crustaceans (61.5%), especially Cladocera. *Diaphanosoma leuchtenbergianum* was particularly abundant. Fish constituted 26.31% of the food and occurred in specimens of various sizes within the range studied. Water boat-

men and midge stages, especially adults, made up 11.56%. Pearse (1915-16) found entomostracans and insects about equally numerous. Forbes (1903) found mayfly nymphs, midge larvae, and fish very abundant in the stomachs examined.

GIZZARD SHAD (*Dorosoma cepedianum*). Seven specimens, 22-31 mm. total length, and taken on June 25 and July 11, 1930 at three Buckeye Lake stations revealed the following: Cladocera, 14.29%; algae and debris, 85.71%.

TABLE 1. SUMMARY OF CONTENTS OF EIGHT SWEET SUCKER (ERIMYZON SUCETTA) STOMACHS FROM FISH TAKEN ON JULY 2 AND 11, 1930, AT TWO BUCKEYE LAKE STATIONS

	8 fish, 30 to 42 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	8	100	53.75	17.25	47
Copepoda (Cyclops)	7	87.5	24.13	3.13	5
C. americanus	4	50.	10.62	1.62	5
Cladocera	7	87.5	29.62	14.12	44
Chydorus sphaericus	4	50.	5.	9.	43
Eurycercus lamellatus	3	37.5	7.5	.38	1
Ceriodaphnia reticulata	3	37.5	15.62	3.25	15
Insecta (Diptera)	4	50.	31.25	1.	3
Chironominae, larvae	2	25.	15.	.5	2
Chironominae, pupae	3	37.5	11.87	.5	2
Debris	3	37.5	15.	-------	---

TABLE 2. SUMMARY OF CONTENTS OF TEN CARP (CYPRINUS CARPIO) STOMACHS FROM FISH TAKEN ON JULY 11 AND 15, 1930, AT TWO BUCKEYE LAKE STATIONS

	10 fish, 23 to 57 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	8	80	51.5	22.	60
Cladocera	7	70	51.0	21.7	60
Camptocercus rectirostris	5	50	11.6	1.9	6
Chydorus sphaericus	7	70	11.7	16.0	50
Eurycercus lamellatus	6	60	27.7	3.8	12
Ostracoda	1	10	.5	.3	3
Insecta (Chironomidae)	6	60	36.5	1.1	5
Chironominae, larvae	4	40	16.5	.6	2
Chironominae (Corynoneura), adults	1	10	10.	1.0	1
Debris	3	30	12.	-------	---

TABLE 3. SUMMARY OF CONTENTS OF 11 BLUNT-NOSED MINNOW (PIMEPHALES NOTATUS) STOMACHS FROM FISH TAKEN ON JULY 2 AND 16, 1930, AT TWO BUCKEYE LAKE STATIONS

	11 fish, 53 to 73 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea (Cladocera)	4	36.36	12.72	8.45	56
Chydorus sphaericus	3	27.27	7.27	6.91	56
Diaphanosoma leuchtenbergianum	1	9.09	1.36	.9	10
Latona setifera	2	18.18	4.09	.64	4
Insecta remains	1	9.09	.9	remains	---
Debris	11	100.	86.36	-------	---
Algae	1	9.09	trace	-------	---

TABLE 4. SUMMARY OF CONTENTS OF 23 GOLDEN SHINER (NOTEMIGONUS CRYSOLEUCAS) STOMACHS FROM FISH TAKEN ON JULY 1 AND 2, 1930, AT TWO BUCKEYE LAKE STATIONS

	22* fish, 23 to 40 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea (Cladocera)	17	77.27	36.14	-------	All in fragments
Scapholeberis mucronata	1	4.54	2.27	.13	3
Chydorus sphaericus	3	13.63	1.59	.32	3
Insecta	11	50.	25.68	.91	4
Chironomidae, adults	5	22.73	11.14	.40	3
Chironominae	3	13.63	7.95	.23	3
Corynoneura	3	13.63	.68	.04	1
Simuliidae	1	4.54	1.59	.04	1
Thripidae, adults	5	22.73	5.91	.27	2
Aphididae, adults	1	4.54	.68	.04	1
Lepidoptera, adults	1	4.54	.23	-------	scales
Hymenoptera, adults	2	9.08	5.91	.09	1
Ichneumonoidea	1	4.54	4.54	.04	1
Eggs (?)	5	22.73	10.23	-------	numerous
Debris	15	68.18	27.95	-------	---

*One fish had no food in its stomach and is omitted from the table.

TABLE 5. SUMMARY OF CONTENTS OF SIX CHANNEL CAT (ICTALURUS PUNCTATUS) STOMACHS FROM FISH TAKEN ON JULY 23 AND AUGUST 5, 1930, AT BUCKEYE LAKE

	5* fish, 31 to 69 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea (Copepoda)	1	20	.2	trace	---
Insecta (Chironomidae)	3	60	23.	1.2	3
Chironominae, larvae	2	40	11.	.8	2
Chironomus, pupae	1	20	10.	.2	1
Debris	4	80	76.8	-------	---

*One fish had no food in its stomach and is omitted from the table.

TABLE 6. SUMMARY OF CONTENTS OF TWENTY-EIGHT BLACK BULLHEAD (AMEIURUS MELAS) STOMACHS FROM FISH TAKEN JULY 17 AND AUGUST 5, 1930, AT FOUR BUCKEYE LAKE STATIONS

	27* fish, 29 to 55 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	26	96.29	74.07	110.6	771
Copepoda (Cyclops)	17	62.96	32.08	18.59	84
C. serrulatus	2	7.40	.26	.26	5
C. americanus	12	44.44	31.81	18.26	84
Cladocera	16	59.26	30.82	89.59	769
Chydorus sphaericus	10	37.04	3.52	58.96	606
Eurycercus lamellatus	11	40.74	12.11	8.55	91
Pleuroxus denticulatus	4	14.81	1.22	4.74	62
Sida crystallina	2	7.40	.11	.22	5
Camptocercus rectirostris	6	22.22	1.52	2.48	24
Simocephalus serrulatus	3	11.11	.67	.33	5
Ceriodaphnia reticulata	5	18.51	7.18	12.11	126
Alona	4	14.81	2.81	1.29	22
A. quadrangularis	2	7.40	2.74	1.22	22
Latona setifera	2	7.40	.37	.07	1
Diaphanosoma leuchtenbergianum	2	7.40	1.29	.81	17
Ostracoda	10	37.04	4.08	1.33	10
Amphipoda (Hyalella knickerbockeri)	8	29.63	7.15	1.07	11
Insecta (Chironomidae)	10	37.04	12.22	2.29	24
Larvae	9	33.33	5.63	1.52	22
Chironominae	7	25.93	4.74	1.26	19
Cricotopus trifasciatus	1	3.7	.22	.04	1
Tanypinae	4	14.80	.67	.15	1
Ceratopogoninae	1	3.7	.37	.04	1
Pupae	3	11.11	2.96	.15	2
Chironomus	1	3.7	2.59	.04	1
Adults	3	11.11	2.22	.63	3
Protenthes	1	3.7	1.29	.44	12
Procladius concinnus	1	3.7	.56	.11	3
Chironomus	1	3.7	.37	.07	2
Debris	11	40.74	13.70	----	---

*One fish had no food in its stomach and is omitted from the table.

TABLE 7. SUMMARY OF CONTENTS OF THIRTY-FOUR TADPOLE CATFISH (SCHILBEODES GYRINUS) STOMACHS FROM FISH TAKEN ON JULY 15 AND 24, 1930, AT TWO BUCKEYE LAKE STATIONS

	33* fish, 16.5 to 33 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	30	90.90	57.76	6.63	19
Cladocera	26	78.78	11.54	2.81	8
Chydorus sphaericus	4	12.12	.27	.36	5
Camptocercus rectirostris	10	30.30	1.24	.82	6
Eurycercus lamellatus	13	39.39	4.51	.57	3
Alona	11	33.3	3.03	.90	7
Copepoda (Cyclops albidus)	2	6.06	.7	.09	2
Ostracoda	15	45.45	13.84	2.06	18
Amphipoda (Hyalella knickerbockeri)	18	54.54	31.67	1.67	7
Insecta	19	57.57	15.76	1.06	5
Chironomidae	15	45.45	13.48	.85	4
Chironominae	13	39.39	12.72	.82	4
larvae	11	33.33	10.5	.67	4
pupae	5	15.15	2.67	.15	1
Ceratopogoninae	1	3.03	.3	.03	1
Ephemerida, nymphs	1	3.03	.15	.03	1
Odonata, nymphs	2	6.06	.67	.06	1
Zygoptera	1	3.03	.6	.03	1
Tapeworms	1	3.03	.54	.03	1
Debris	23	69.69	25.76	----	1

*One fish had no food in its stomach and is omitted from the table.

TABLE 8. SUMMARY OF CONTENTS OF THIRTY-FOUR BROOK SILVERSIDE (LABIDESTHES SICCULUS) STOMACHS FROM FISH TAKEN ON JULY 2, 1930, AT THREE BUCKEYE LAKE STATIONS

	34 fish, 19 to 37 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	32	94.12	49.82	21.65	64
Copepoda (Cyclops americanus)	10	29.41	15.56	8.47	60
Cladocera	32	94.12	34.26	13.18	62
Scapholeberis mucronata	26	76.47	31.31	10.82	56
Chydorus sphaericus	14	41.18	1.63	1.94	12
Camptocercus rectirostris	3	8.32	.53	.29	6
Sida crystallina	1	2.94	.14	.06	2
Alona guttata (?)	1	2.94	.03	.06	2
Rotifera (?)	2	5.88	.62	----	--
Eggs (?)	6	17.65	7.24	----	--
Insecta	26	76.47	41.44	4.56	19
Chironomidae, adults	15	44.12	21.38	1.59	8
Chironominae	6	17.65	11.44	.62	8
Orthocladius	2	5.88	2.21	.24	5
Tanytarsus	2	5.88	.88	.09	2
Corynoneura	4	11.76	1.62	.27	4
Cricotopus	1	2.94	.32	.06	2
Chironomus	4	11.76	7.77	.47	8
Tanypinae	2	5.88	2.5	.15	4
Protenthes	2	5.88	1.77	.12	3
Tanypus	1	2.94	2.06	.12	4
Chironomidae (Tanypinae), pupae	1	2.94	1.32	.03	1
Chironomidae (Chironominae) larvae	1	2.94	.09	.03	1
Simuliidae, adults	1	2.94	.23	.03	1
Psychodidae, adults	1	2.94	.15	.03	1
Aphididae, adults	8	23.53	4.94	.59	11
Hemiptera, nymphs	2	5.88	2.12	.24	7
Miridae (?)	1	2.94	.06	.03	1
Thysanoptera, adults	19	55.88	11.12	1.97	11
Thripidae	17	50.	10.79	1.91	11
Aeolothripidae (Aeolothrips fasciatus)	1	2.94	.14	.03	1
Chalcididae, adults	1	2.94	.09	.03	1
Arachnida (Oribatidae)	1	2.94	.15	.03	1
Debris	1	2.94	.73	----	--

TABLE 9. SUMMARY OF CONTENTS OF ONE HUNDRED THIRTY-SEVEN WHITE CRAPPIE (POMOXIS ANNULARIS) STOMACHS FROM FISH TAKEN FROM JUNE 25 TO AUGUST 7, 1930, AT NINE BUCKEYE LAKE STATIONS

	136* fish, 15 to 60 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	135	97.79	91.19	25.66	177
Cladocera	113	83.09	50.65	18.07	166
Diaphanosoma leuchtenbergianum	70	51.47	21.66	8.35	133
Sida crystallina	10	7.35	2.95	.16	7
Chydorus sphaericus	16	11.8	1.35	.625	16
Ceriodaphnia reticulata	49	36.03	11.31	7.69	160
Leptodora kindtii	25	18.38	12.42	.71	12
Bosmina	7	5.15	.19	.19	8
Daphnia pulex	2	1.47	.21	.44	5
Camptocercus rectirostris	3	2.20	.11	.07	6
Alonella	1	.73	.07	.007	1
Alona	8	5.88	.12	.08	2
Kurzia latissima	1	.73	.02	.007	1
Copepoda (Cyclops)	109	80.15	39.86	7.57	57
C. serrulatus	1	.73	.33	.02	3
C. leuckarti	5	3.68	.53	.04	2
C. americanus	65	47.79	24.72	3.31	55
Amphipoda (Hyalella knickerbockeri)	3	2.20	.58	.02	1
Insecta	28	20.5	3.64	.28	3
Chironomidae	20	14.70	3.09	.22	3
Larvae	19	13.97	2.54	.20	3
Chironominae	17	12.53	2.38	.19	3
Chironomus	1	.73	.03	.007	1
Pupae	3	2.20	.52	.03	2
Chironominae	2	1.47	.38	.02	2
Adults	1	.73	.02	.007	1
Debris	29	21.23	5.16	----	--

*One fish had no food in its stomach and is omitted from the table.

TABLE 10. SUMMARY OF CONTENTS OF FIFTY-THREE BLUE GILL (HELIOPERCA INCISOR) STOMACHS FROM FISH TAKEN FROM JULY 24 TO AUGUST 7, 1930, AT FOUR BUCKEYE LAKE STATIONS

	53 fish, 21 to 37 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	53	100.	86.21	26.94	155
Copepoda (Cyclops)	44	83.02	35.17	9.26	34
C. americanus	23	43.39	14.81	3.64	30
C. serrulatus	1	1.89	.06	.07	4
C. albidus	8	15.09	2.15	.04	5
Cladocera	53	100.	36.22	16.94	135
Bosmina longirostris	8	15.09	1.24	1.81	50
Ceriodaphnia reticulata	14	26.41	8.89	7.08	85
Eurycercus lamellatus	11	20.76	4.24	.04	3
Simocephalus serrulatus	3	5.66	.38	.09	2
Chydorus sphaericus	12	22.64	2.49	2.08	30
Alona guttata (?)	16	30.18	1.81	1.23	13
Pleuroxus rectirostris	2	3.77	.23	.11	3
Scapholeberis mucronata	9	16.98	1.94	.71	20
Diaphanosoma leuchtenbergianum	6	11.32	1.77	1.89	25
Sida crystallina	16	30.18	10.83	1.39	20
Latona setifera	3	5.66	1.26	.08	2
Amphipoda (Hyalella knickerbockeri)	16	30.18	14.83	.56	5
Insecta	24	45.28	13.23	1.32	24
Chironomidae	21	39.61	12.53	1.30	24
Larvae	21	39.61	12.06	1.27	23
Chironominae	20	37.72	11.15	1.11	17
Tanypinae	2	3.77	.71	.13	6
Pupae (Chironominae)	2	3.77	.47	.04	1
Coenagrionidae, nymphs	1	1.89	.28	.02	1
Debris	2	3.77	.56	—	—

TABLE 11. SUMMARY OF CONTENTS OF THIRTEEN COMMON SUNFISH (EUPOMOTIS GIBBOSUS) STOMACHS FROM FISH TAKEN ON JULY 24, 1930, AT BUCKEYE LAKE

	13 fish, 24 to 32 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	13	100.	77.56	39.61	115
Copepoda (Cyclops)	6	46.15	2.77	.69	3
C. leuckarti	3	23.08	.92	.38	3
Amphipoda (Hyalella knickerbockeri)	9	69.23	31.15	1.92	5
Cladocera	13	100.	43.61	37.	113
Ceriodaphnia reticulata	13	100.	29.29	34.38	110
Eurycercus lamellatus	6	46.15	8.	.61	2
Alona	2	15.38	.61	.45	4
A. affinis	2	15.38	.38	.15	1
A. quadrangularis	1	7.69	.23	.30	4
Camptocercus rectirostris	4	30.76	.85	.30	1
Latona setifera	4	30.76	4.69	1.08	10
Chydorus sphaericus	2	15.38	.17	.16	1
Insecta	7	53.85	12.08	.61	2
Chironominae, larvae	5	38.46	10.15	.61	2
Debris	7	53.85	10.38	—	—

TABLE 12. SUMMARY OF CONTENTS OF ONE HUNDRED TWELVE LARGE-MOUTH BASS (APLITES SALMOIDES) STOMACHS FROM FISH TAKEN FROM JULY 1 TO AUGUST 7, 1930, AT EIGHT BUCKEYE LAKE STATIONS

	112 fish, 21 to 112 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	102	91.07	59.40	61.38	381
Copepoda (Cyclops)	45	40.18	2.28	1.88	17
C. americanus	19	16.96	.52	.46	6
C. serrulatus	14	12.5	.83	.77	15
C. albidus	14	12.5	.5	.22	5
C. fuscus	2	1.79	.04	.08	8
C. leuckarti	3	2.68	.05	.04	1
C. ater	1	.89	.02	.01	1
Cladocera	92	82.14	38.76	57.45	367
Chydorus sphaericus	4	3.57	.05	.09	4
Sida crystallina	32	28.57	11.85	6.51	81
Ceriodaphnia reticulata	34	30.36	7.03	22.11	287
Eurycercus lamellatus	46	41.07	7.03	1.82	28
Scapholeberis mucronata	35	31.25	10.15	25.39	348
Latona setifera	16	14.29	1.04	.84	61
Diaphanosoma leuchtenbergianum	10	8.93	.37	.75	27
Kurzia latissima	1	.89	.01	.01	1
Simocophalus serrulatus	24	21.43	1.26	.83	17
Bosmina	1	.89	.01	.02	2
Ostracoda	10	8.93	.12	.09	2
Amphipoda (Hyalella knickerbockeri)	57	50.89	18.24	2.02	21
Arachnida	2	1.79	.81	.02	1
Araneida	1	.89	.71	.01	1
Fish	7	6.25	5.08	.08	2
Aplites salmoides (?)	1	.89	.27	.01	1
Noturus flavus	1	.89	.85	.01	1
Insecta	70	62.5	34.25	1.94	36
Ephmerida, nymphs	13	11.61	3.5	.15	6
Baetinae	6	5.36	2.1	.09	6
Ameletus	2	1.79	.71	.01	1
Ephemerinae (Caenis)	5	4.47	.59	.04	1
Odonata, nymphs	30	26.79	13.51	.49	6
Zygoptera	28	25.	12.75	.46	6
Anomalagrion	2	1.79	.94	.02	1
Enallagma	21	18.75	9.35	.38	6
Hemiptera (unidentified nymphs)	2	1.79	.22	.02	1
Corixidae	23	20.54	8.03	.41	12
Palmacorixa buenoi	8	7.14	4.32	.24	12
Aphididae	1	.89	.09	.01	1
Diptera (unidentified adults)	1	.89	.02	.01	1
Chironomidae, larvae	35	31.25	4.60	.70	30
Chironominae	26	23.21	2.53	.32	3
Chironomus	6	5.36	1.03	.07	2
C. fulviventris	3	2.68	.64	.04	2
Cricotopus	5	4.47	.32	.07	2
C. trifasciatus	4	3.57	.23	.05	2
Orthocladius (?)	1	.89	.06	.01	1
Tanytarsus	2	1.79	.12	.03	2
Tanypinae	4	3.57	.37	.04	1
Tanypus monilis (?)	1	.89	.22	.01	1
Ceratopogoninae	4	3.57	1.11	.30	30
Palpomyia	2	1.79	.42	.03	2
Chironomidae, pupae	12	10.71	2.40	.16	6
Chironominae	2	1.79	.44	.02	1
Tanypinae	1	.89	.12	.01	1
Ceratopogoninae	4	3.57	.79	.08	6
Palpomyia	3	2.68	.65	.07	6
Chironomidae (Chironomus) adults	2	1.79	.38	.02	1
C. crassicaudatus	1	.89	.30	.01	1
Mycetophilidae, adults	1	.89	.18	.01	1
Acalyptratae, adults	2	1.79	.34	.02	1
Ephydridae	1	.89	.16	.01	1
Debris	4	3.57	.46	---	

TABLE 13. SUMMARY OF CONTENTS OF SIXTY YELLOW PERCH (PERCA FLAVESCENS) STOMACHS FROM FISH TAKEN FROM JULY 2 TO AUGUST 7, 1930, AT FIVE BUCKEYE LAKE STATIONS

	59* fish, 45 to 162 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	51	86.44	59.84	30.59	300
Copepoda (Cyclops)	30	50.85	17.26	14.86	280
C. americanus	21	35.6	12.22	9.28	150
C. serrulatus	2	3.39	.31	.37	18
C. leuckarti	3	5.09	.12	.05	1
C. fuscus or albidus	1	1.69	.02	.02	1
Cladocera	43	72.88	24.07	13.2	188
Latona setifera	11	18.64	3.39	1.17	20
Sida crystallina	19	32.2	8.52	1.7	17
Ceriodaphnia reticulata	15	25.42	2.	6.6	180
Diaphanosoma leuchtenbergianum	2	3.39	.07	.17	6
Eurycercus lamellatus	21	35.6	6.86	2.26	24
Chydorus sphaericus	6	10.17	.27	.27	5
Simocephalus serrulatus	7	11.87	2.4	.54	21
Camptocercus rectirostris	4	6.78	.12	.08	2
Alona quadrangularis	5	8.47	.33	.41	11
Ostracoda	4	6.78	.10	.10	2
Amphipoda (Hyalella knickerbockeri)	24	40.69	18.54	2.42	22
Insecta	36	61.01	31.48	2.42	15
Chironomidae	29	49.16	14.81	1.47	11
Larvae	28	47.47	11.32	1.17	9
Chironominae	25	42.38	9.03	.96	9
Tanypinae	5	8.47	1.74	.13	3
Ceratopogoninae	1	1.69	.17	.02	1
Pupae	10	16.95	3.61	.31	4
Chironominae	6	10.16	2.89	.17	4
Chironomus	4	6.78	2.66	.09	2
Ephemeridae, nymphs	3	5.09	1.10	.05	1
Boetinae, nymphs	1	1.69	.17	.01	1
Zygoptera, nymphs	8	13.56	4.64	.34	7
Enallagma (?)	5	8.47	3.79	.17	4
Psocidae	1	1.69	.05	.01	1
Trichoptera, larvae	1	1.69	.10	.01	1
Debris	21	35.6	8.56	----	--

*One fish had no food in its stomach and is omitted from the table.

TABLE 14. SUMMARY OF CONTENTS OF TWENTY-EIGHT LOG PERCH (PERCINA CAPRODES) STOMACHS FROM FISH TAKEN ON JULY 2 AND 11, 1930, AT THREE BUCKEYE LAKE STATIONS

	28 fish, 42 to 59 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	28	100.	67.87	55.6	280
Copepoda (Cyclops)	20	71.42	17.69	30.28	265
C. americanus	11	39.28	7.82	18.07	185
Ostracoda	2	7.14	.21	.07	1
Amphipoda (Hyalella knickerbockeri)	3	10.71	2.03	.17	3
Cladocera	26	92.85	47.92	25.07	89
Latona setifera	11	39.28	9.35	2.93	18
Ceriodaphnia reticulata	16	57.14	13.89	11.68	86
Simocephalus	4	14.28	1.21	.3	7
Bosmina longirostris	8	28.56	1.43	4.06	49
Pleuroxus denticulatus	1	3.57	.107	.06	2
Eurycercus lamellatus	5	17.85	1.5	.38	4
Sida crystallina	13	46.42	18.5	3.89	28
Camptocercus rectirostris	9	32.13	1.72	1.8	17
Alona quadrangularis (?)	1	3.57	.04	.03	1
Insecta	23	82.14	30.70	3.78	20
Chironomidae	23	82.14	28.69	3.57	20
Chironominae, larvae	17	60.71	20.09	2.67	20
Tanypinae, larvae	2	7.14	.64	.07	1
Ceratopogoninae, larvae	1	3.57	1.07	.03	1
Chironominae, pupae	4	14.28	.68	.14	1
Ephemerida (Baetinae), nymphs	1	3.57	.17	.03	1
Debris	2	7.14	1.43	----	--

TABLE 15. SUMMARY OF CONTENTS OF SIXTEEN WHITE BASS (LEPIBEMA CHRYSOPS) STOMACHS FROM FISH TAKEN ON JULY 16 AND AUGUST 5, 1930, AT TWO BUCKEYE LAKE STATIONS

	16 fish, 54 to 96 mm. total length				
Food organisms	No. of stomachs	Per cent of total No. of stomachs	Average % of food by vol. (estimated)	Average number of animals	Greatest No. of animals in any one stomach
Crustacea	14	87.5	61.5	227.8	880
Copepoda	11	68.75	2.31	1.75	4
Cyclops	8	50.	1.5	1.19	4
C. leuckarti	4	25.	.56	.5	4
Argulus	3	18.75	.81	.56	4
A. stizostethi	1	6.25	.25	.25	4
Cladocera	14	87.5	59.19	226.	878
Sida crystallina	1	6.25	.63	.19	3
Daphnia	2	12.5	.37	.25	2
Leptodora kindtii	8	50.	6.87	1.87	9
Diaphanosoma leuchtenbergianum	10	62.5	40.44	123.9	473
Latona setifera	1	6.25	.37	.19	3
Fish	6	37.5	26.31	.5	2
Lepibema chrysops	2	12.5	10.	.25	2
Insecta	10	62.5	11.56	1.56	10
Hemiptera (Corixidae)	4	25.	6.89	1.06	10
Chironomidae	6	37.5	4.69	.5	2
Chironomidae (Chironominae), larvae	3	18.75	.87	.25	2
Chironomidae, pupae	1	6.25	.5	.12	2
Chironominae	1	6.25	.19	.06	1
Chironomidae (Chironomus), adults	1	6.25	3.12	.06	1
Debris	1	6.25	.63	—	—

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Discussion

Mr. Eugene Surber: May I ask Dr. Ewers what was found with regard to the food of the blunt-nosed minnow?

Dr. Ewers: Eleven fish were examined, taken from two stations, July 2 and 16. The summary shows: crustacea, practically all Cladocera, 12.73%; insecta remains, .9%; debris, 86.37. There were traces of algae. This investigation, although not very extensive, agrees with Forbes and Kraatz, in that it showed they ate much debris with a few algae and some crustacea. Evidently feeds around vegetation. The food in all of the fishes was in very bad condition.

Mr. Eugene Surber: We are particularly interested in the blunt-nosed minnow because we have been using it at Leetown as a forage minnow in our bass pond. I am glad to hear that Dr. Ewers finds such a large percentage of debris, probably plant remains, in the digestive tracts of this species.

Mr. Marcus: I was wondering whether the ostracods were disintegrated or digested, or whether you could identify them.

Dr. Ewers: We did not try to identify the ostracod, although I believe it could have been done. Such a small number of these fish took ostracods in any quantity whatsoever that we merely called them ostracods. I believe they were not usually digested. In some fish the food is always badly fragmented while in others it is practically always in more or less well preserved condition. I would say as a rule that ostracods were in a well preserved condition. It would be impossible to make any complete conclusions because ostracods were found in only a few of the fish studied.

Dr. Wiebe: I think one thing that is neglected in the study of the natural food of fishes is the question of availability of the food. When we find that the fish has been eating more of one type of food than of another, is it because the fish prefers that food, or is it because it is the only food the fish can get? That is something that should be considered before we can decide whether the fish exercise any judgment in the matter, have a sense of selection, or whether they just take what comes across their path. Recently in Texas I examined the

stomachs of a number of black crappie and I found a preference for water mites; I found live mites not only in the stomach but in the intestine, and here the question suggested itself whether they were digested at all. In other cases I found they were pretty well digested.

Another interesting thing: I was studying different sizes of young crappie and formed the notion, provisionally, that the larger crappie distinctly preferred insect larvae to entomostraca. When it came to the largest crappie I had in the group—the fish were taken out of different ponds—the entire stomach and the entire intestine were completely filled with cereodaphnia. I imagine the only reason for that would be that these organisms were abundant in that pond; it was not at all a matter of preference.

The President: If we find that fifty per cent of the food in a certain fish consists of beetle larvae and fifty per cent of entomostraca, we are interested in the question how many pounds of fish that food will produce. We therefore should determine the nutritive value of each kind of food consumed, since we are interested primarily in the production of pounds of fish for the fishermen to catch. Are there any further comments?

Mr. Eugene Surber: My master's thesis was on the subject of the food of fishes in relation to available food. In making my collections of fish—these collections were made with a fairly large seine—plankton samples were taken within the area covered by the seine. Mr. Markus put a question to Dr. Ewers about ostracods as food. In the Mississippi river sloughs we find that ostracods are extremely abundant, often exceeding twenty thousand per square liter of bottom area, and yet hardly a trace of ostracods was found in the food of any of these slough fishes taken within the seine haul.

LOGICALLY JUSTIFIED DEDUCTIONS CONCERNING THE GREAT LAKES FISHERIES EXPLODED BY SCIENTIFIC RESEARCH

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The extremes of my title may seem to be antithetic. One would hardly expect logically justified deductions to conflict with sound scientific research. It is, however, largely a question of "before and after" — deductions before an investigation, the conflict after it. Cases where indisputable deductions and sound research conflict are perhaps not common, but in our investigations of the fisheries of the Great Lakes we were fortunate, or perhaps unfortunate, in having encountered several such situations. These proved to be highly illuminating in that they very emphatically stressed the point that in scientifically sound research nothing can be taken for granted; all deductions and assumptions, no matter how logically sound or how irrefutable they may appear to be, must be put to practical tests whenever possible.

Because the examples taken from the Great Lakes investigations show in a striking manner how soundly deduced conclusions may be completely invalidated by scientific research, they will be of some general interest. They should place other fisheries biologists on guard in accepting too readily or in placing too much emphasis on conclusions based wholly or in part on indirect or presumptive evidence. My illustrations will be drawn from three different types of research—research on the selective action of commercial fishing gear, on fishery statistics, and on pollution.

Selective Action of Fishing Gear

How would you answer this question: Will an increase in the size of mesh gill nets and impounding nets always reduce the number of small fish taken in the catch? On some reflection you would reason as follows: Bigger fish can pass through a large mesh than through a small one. Because of increasing mortality with age larger fish are less abundant in the lake, hence less available, than the smaller. Therefore, an answer in the affirmative must be correct. We fully agreed with this answer but that was during the "before" stage; during the "after" our perfectly good logic was shot full of holes.

In at least three important experiments studies on the selective action of nets failed to support our deductions. In the case of the yellow perch of Lake Erie it was found that in a series of experimental gill nets with meshes that ranged from 2¾ to 3⅛ inches, there was, it is true, the expected progressive decrease in the number

of perch taken, of both legal and illegal length, with each successive increase in the size of mesh, but it was also determined that when the mesh was still further increased to 3¼ and 3½ inches the average number of undersized perch taken suddenly increased to a marked degree, while peculiarly enough the number of legal perch continued to decline. Apparently small perch are more readily entangled by their teeth in large mesh than in small mesh gill nets.

The most disconcerting contradiction came from our experiments on the selective action of chub gill nets on baby lake trout in Lake Michigan. The results of these experiments were so decidedly in conflict with all reasonable expectations that the work was repeated and continued through three seasons. I was so certain that the large mesh gill nets would take the smallest number of baby trout that in 1929 I indicated in a published statement, based on preliminary experiments, that this must be true because the larger mesh takes a larger trout (which was found to be true) and therefore draws upon a less abundant trout stock. However, extensive experimentation invalidated this deduction. In a series of experimental gill nets with meshes that ranged from 2⅜ to three inches, it was found that the smallest mesh net instead of taking the greatest number of lake trout took the fewest, and that the number of trout taken in the 2½, 2⅝, and 2¾ inch mesh nets instead of showing respectively either a progressive decrease or increase, remained constant—there was no selective action. There was, however, a slight decrease in the number of trout taken in the three inch mesh gill nets. Apparently lake trout of the sizes covered by the experimental meshes, the 2⅜ and three inch excepted, were equally abundant in the lake.

The two examples just cited involved gill nets. But, you say, impounding nets will certainly release fish if the mesh is large enough. The fish are alive and unusually active when trapped. It is true our extensive experiments on the trap nets of Lake Erie did demonstrate convincingly that impounding nets will almost invariably sort out the small fish on the basis of the size of the mesh employed, but, nevertheless, we can not predicate with safety that such sorting will always occur. This was demonstrated by our experiments on the herring pound nets of Saginaw Bay. These studies indicated that the smaller herring escaped through the larger meshes in the spring of the year but not in the fall. It is probable that the advent of spawning accounted for the difference in behavior.

It is evident then that the categorical reply to the question under consideration needs a considerable number of "savings clauses" in order to make it correspond with the actual facts.

Let us forget our failure in obtaining a perfect score on the first question advanced. Perhaps the second one on fishing gear will do us more justice. I ask: Would you expect to increase the catch of legal sized fish taken in impounding nets by increasing the size of the mesh in the lifting crib of such nets? In this case we reason as fol-

lows, and in this reasoning we probably have every commercial fisherman of the Great Lakes on our side: It is known that in the case of gill nets the size of mesh must be regulated in accordance with the size of the majority of the legal sized fish on the grounds in order to obtain the most successful fishing. Thus, a five-inch mesh gill net will take more legal sized whitefish than a four-inch mesh gill net when set in the Michigan waters of the Great Lakes.

But impounding nets act on a different principle; they do not catch fish by gilling them. Hence, the mesh of such nets would not seem to be an important factor in the capture of legal sized fish as long as it is small enough to prevent the escape of such fish. Thus the logical reply to the second question must be "No." An impounding net with a small mesh can certainly catch as many fish as one with a larger mesh. But here again experimental studies explode the deductions at least with respect to three very important species of fish. These studies showed that the catch of legal sized yellow pike-perch, yellow perch, and whitefish could be increased by as much as eighteen per cent when the mesh of the lifting crib was increased in size. These unexpected results may perhaps be explained on the theory that these three species of fish react negatively to darkness and therefore avoid an impounding net darkened by small meshes.

Fishery Statistics

For my next illustration I shall turn to the field of fishery statistics. As many of you know, the most recent trend in studies on abundance of fish is to express the catch in terms of fishing intensity, which is usually defined as "the catch per unit gear per unit fishing time." It is rather generally conceded by all fisheries biologists that in order to obtain a true measure of the abundance of fish on the fishing grounds it is necessary to consider not the total quantity of fish taken but the quantity taken by some unit quantity of gear per some unit quantity of time (when time is a factor involved).

For example, let it be assumed that two pound nets are fished concurrently and on the same grounds for a period of ten days. Let it be assumed further that one of these nets is lifted daily while the other is lifted every two days. Thus the one net will be lifted ten times, the other five times in ten days. Consequently, it may be expected that the average catch per lift of the net visited every two days will be approximately twice that of the net lifted daily. This sounds perfectly reasonable, does it not? If one pound net averages 100 pounds of whitefish per lift for each day's fishing then for each two days of fishing it should take on the average 200 pounds per lift—a very obvious conclusion that no one would care to contradict. Perhaps no one but a brazen skeptic would question it! However, in view of the fact that our chain of reasoning has been snapped so often by actual tests we have decided to check even this clear-cut postulation. Dr. Ralph Hile of the Bureau's Great Lakes staff is at present

engaged on this problem. His figures given in the accompanying tables, although not yet complete, show conclusively that a serious discrepancy exists between the theoretical deductions and the actual facts.

The catch of fish in impounding nets lifted every two days is far from double that of nets lifted daily. Table 1 shows that on the average the catch of the two-day nets is only about twenty per cent greater than that of the one-day net. Other figures in the tables show even more striking discrepancies. The data show that the time element is actually involved in the fishing intensity and must be considered, but not on a strictly unit basis as described above. Thus, for example, if the catch of the Green Bay pound nets that were lifted every day is placed on the basis of 100 pounds of fish per net, then the same nets operated on the same grounds during identically the same period of time but lifted every two days produce only 117 pounds per net, not the theoretical 200 pounds, and whereas the actual abundance of the fish expressed in terms of fishing intensity would be 100 pounds per net per day when based on one day's fishing, it would be only 58½ pounds per net per day when based on two days' fishing.

It may be seen, then, that an entirely wrong picture is presented of actual conditions when the "catch per unit time" is employed for nets without regard to the length of time they were left in the water. This is really a startling revelation and forces a revision of the commonly accepted connotation of the definition of fishing intensity. We shall

TABLE 1. EFFECT OF FISHING TIME ON SIZE OF LIFT (ALL SPECIES COMBINED) IN DIFFERENT IMPOUNDING NETS. THE DATA FOR THE AVERAGE LIFT AT DIFFERENT FISHING TIMES FOR ALL TYPES OF NETS HAVE BEEN PRESENTED ON THE PERCENTAGE BASIS, WITH THE CATCH OF NETS ONE NIGHT OUT SET ARBITRARILY AT 100 POUNDS OR 100 PER CENT. BASED ON STATE OF MICHIGAN STATISTICS

Number of Nights Out	1	2	3	4	5	6	7
Theoretical catch	100	200	300	400	500	600	700
Catch in pound nets (Green Bay)	100	117	126	137	114*	......	......
Catch in Fyke nets (Lake Erie)	100	116	131	149	131*	......	......
Catch in shallow trap nets (Saginaw Bay)	100	120	130	139	163	170	187
Average of pound, Fyke, shallow trap nets	100	118	128	139	142	......	......
Catch in deep trap nets (Harbor Beach)	100	130	152	161	151*	......	......
Average in impounding nets	100	122	136	146	142*	......	......

*Less than preceding lift.

TABLE 2. EFFECT OF FISHING TIME ON THE AVERAGE LIFT OF CHUB GILL NETS. (THE LIFT OF A GANG FOUR NIGHTS OUT IS SET ARBITRARILY AT 400 POUNDS; CONSEQUENTLY EACH ADDITIONAL NIGHT OUT SHOULD THEORETICALLY ADD 100 POUNDS TO THE LIFT.) BASED ON MICHIGAN'S FISHERY IN NORTHERN LAKE HURON (DISTRICT I) FOR THE YEARS 1930-1933, INCLUSIVE

Fishing time (nights out)	4	5	6	7	8	9	10	11
Theoretical lift	400	500	600	700	800	900	1,000	1,100
Actual lift	400	446	510	547	588	626	622	542

probably have to describe abundance in terms of "the average net lift, corrected for fishing time" rather than in terms of the "average catch per net per night" as we now do. And, by the way, skepticism and critical research score another point!

Pollution

The last example to be considered in this tirade against preconceived notions is probably one of the most sensational. I refer to the firmly established and traditionally accepted misconception concerning the degree of the effect of pollution on the fisheries of Lake Erie, especially those of the area west of the Sandusky Bay region. If pollution is a major factor anywhere on the Great Lakes in depleting the commercial fisheries, it must be very evident in western Lake Erie. Here is located a very shallow body of water with a mean depth of only 25 feet that is partially shut off from the rest of Lake Erie by islands and peninsulas and that receives each day some 366,000,000 gallons of industrial waste and sewage contributed by more than 2,164,000 persons residing in Detroit, Windsor, Monroe, Toledo, and smaller cities.

To make the case still stronger it may be recalled that this region of the lake provides the most intensive fishing and includes the most important spawning grounds found anywhere in the lake. Every commercial species of fish found in the lake, except the blue pike, finds its most important spawning grounds in this region. Further, the whitefish, the sauger, and perhaps other species, formerly migrated in large numbers into the extreme western end of this area along the Michigan shore but have now deserted these waters. Finally, to clinch the argument, the International Joint Commission reported, on the basis of many bacteriological tests made in 1913, that this area was the most seriously affected by pollution in the entire Great Lakes system. It is obvious therefore why no one ever challenged the statements repeatedly made that pollution played a major role in the decline of the fisheries of western Lake Erie, if not of the entire lake. Not until the results of the preliminary investigations conducted in 1926 by the Division of Conservation of the State of Ohio were made public were serious doubts cast upon these assertions. Subsequent investigations, however, have fully substantiated the astonishing conclusions of the preliminary survey and showed that serious pollution of a character that could affect the fisheries adversely did not extend far into the lake but was confined to small areas near the mouths of the contaminated streams. Thus another cock-sure belief fell before the onslaught of science.

Time does not permit a continuance of this hurling of bombshells against the foundations of our mental superstructures. Enough has been related to convince anyone that in order to be a good scientist one must be a good skeptic!

A PRELIMINARY REPORT UPON A HATCHERY DISEASE OF THE SALMONIDAE

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In June, 1934, an outbreak of disease occurred among the brook and brown trout at a Massachusetts State fish hatchery. Through the courtesy of J. Arthur Kitson, Biologist of the Massachusetts Division of Fisheries and Game, material for pathologic and bacteriologic study was obtained. The disease with its varied symptomatology presented a rather complex picture of organic and functional changes, some indicative of metabolic disturbances and others manifestly the result of reaction against an infectious agent.

In spite of the fact that many points are still undetermined and final conclusions cannot be drawn, the pathologic picture has sufficient interesting features to warrant the presentation of a preliminary report. A comprehensive study of the disease, which has made further inroads during 1935, is now being made by the State Department.

Pathology

The description of the lesions, except for an occasional histological reference, is confined to their gross pathology. The lesions associated with the disease fall into two main groups: (1) external and (2) internal, and involve nearly all the tissues. The variety and extent of the lesions depend upon the resistance of the trout, being more diversified and extensive in the resistant individuals. The disease, which has a selective affinity for the kidney, is primarily associated with the vascular system and body fluids as is shown by (1) tissue edema, (2) inflammation of the serous cavities, and (3) hemorrhagic tendencies. The incidence of the various lesions in 74 trout is shown below:

Location of Lesion	*Incidence (Per Cent)*
Skin and muscles (blebs, ulcers, and abscesses)	60
Kidney	53
Eye (popeye)	30
Heart and pericardium	26
Liver	23
Peritoneum	22
Reproductive Organs	15
Spleen	9

1. External Lesions

Exophthalmos. The most striking symptom of the disease is the protrusion of one or both eyes, popularly known as "popeye." This condition is found in several diseases and may result from various causes. It occurs in the "gas bubble" disease, which is due to supersaturation of the water with air (Marsh and Gorham, 1905). It has been produced by encysted trematode larvae on the optic nerve (Ward and Mueller, 1926). It may result from any inflammation near the orbital cavity. Davis (1934) found "popeye" associated with serous effusion in the peritoneal cavity with and without kidney pathology.

In this disease the exophthalmos is due to edema and serous effusion. In most cases the underlying cause appears to be renal insufficiency resulting from the destruction of kidney tissue. "Popeye" was present in about 20 per cent of the diseased fish observed at the hatchery and in 30 per cent of the trout selected for autopsy.

Blebs. Superficial lesions in the form of blebs or blisters of various sizes were frequently observed during the period of maximum mortality. The unruptured bleb appears as a raised circular or elliptical area of skin separated by fluid from the underlying tissues. The blebs, which vary in size from 1 to 40 millimeters, may appear on any part of the body except the head, tail, and fins, but are usually present on the sides above the lateral line.

The raised skin over the bleb is of light color and is often denuded of scales. Several blisters may coalesce to form an extensive separation of flesh and skin with only occasional connecting strands. When multiple, they are usually of small size, but not infrequently, especially in rainbow trout, only a single, large, rapidly growing blister is present.

The contents of the blebs vary from a clear amber fluid to blood-tinged, turbid, or frankly purulent material, consisting of cells, bacteria, and granular debris. In over one-half the cases there is little or no invasion of the muscles except for a slight hemorrhagic tinge. In such cases the fluid contents are clear, hemorrhagic, or only slightly turbid. In slightly less than half the cases there is a variable amount of superficial dissolution of the muscles not exceeding a depth of five millimeters. When the muscle is involved, it is pitted and infiltrated with a bloody, viscous, markedly turbid fluid. At times there is a deep red area extending along the intermuscular fascia, and occasionally the whole content is a mass of red, disintegrated tissue.

When the distended skin of the bleb ruptures, the content escapes, leaving a denuded area. These depressions are superficial, with a shallow base of white or slightly hemorrhagic muscle. The edges though ragged are not undermined or steep.

Abscesses. Instead of forming superficial blebs, collections of thick white or hemorrhagic turbid fluid may localize deep in the muscles. There is sloughing of the muscles and a tendency for the fluid to burrow along the intermuscular fascia. These abscesses are found

most frequently in the neighborhood of the kidneys and in the ventral triangle between the pectoral fins.

Hemorrhagic Areas. The bases of the pectoral fins may be reddened. The under side of the operculum may show increased congestion. The eyes frequently have a slight hemorrhage at the lower margin and at times there is an intra-orbital collection of hemorrhagic fluid.

2. Internal Lesions

Pratically all the organs are involved, but more particularly the kidneys, serous cavities, liver, and spleen. The extent and type of the lesions vary widely in different fish.

Kidneys. The kidneys are most frequently affected, over fifty per cent of the cases showing gross lesions, and practically all microscopic. All grades of lesions from small circumscribed abscesses to extensive destruction of kidney tissue are found. In the early cases one or more small grayish white areas, two to five millimeters in diameter, may be observed beneath the capsule on the ventral surface. They usually contain a thick white finely-granular fluid consisting of cells, leucocytes, bacteria, and cellular debris, but occasionally they are firm and friable. As the disease progresses the number and size of these abscesses increase. In resistant trout they may coalesce to form a large grayish-white abscess, with the destruction of an extensive area of kidney substance, and in some instances even invade the adjoining body wall. No correlation has been observed between the degree of kidney involvement and the presence of lesions in other organs. In a few instances where no local abscesses were observed, the kidney capsule was distended by a hemorrhagic exudate. Microscopically the kidneys show both acute and chronic histologic lesions with areas of recent necrosis side by side with partially healed lesions. There is extensive destruction of both the glomeruli and the supporting structure.

Peritoneum. The disease is characterized by an excess of fluid in the tissues and in the serous cavities, particularly the peritoneum and pericardium. About one-fifth of the trout show an excess of fluid in the peritoneum. Usually the ascitic fluid is a clear amber effusion, but it may be hemorrhagic. Sometimes masses of soft-clotted blood are present. No turbid or purulent ascitic fluid has been observed.

Pericardium. About one-fourth of the trout which come to autopsy have pericardial effusion. Nearly all the cases show some stage of pericarditis, from slight fibrinous changes to an advanced fibrinous pericarditis with plastic adhesions and purulent effusion. The visceral pericardium is pale and is covered with small and large white plaques or a shaggy exudate. The pericardial effusion usually varies from a white turbid to a frankly purulent fluid and from a small amount to that sufficient to cause marked distention of the pericardium. The visceral and parietal pericardium may be covered by a shaggy exudate

and bound together by fibrinous adhesions. In one instance there was an hemorrhagic effusion.

Liver. Slightly over one-fifth of the cases show the presence in the liver of small white abscesses similar to those in the kidneys. These abscesses vary as to number and size. In a typical case the ventral surface of the liver is studded with white spots of pin point size. The liver substance has a discolored or mottled appearance.

Spleen. Ordinarily the spleen, except for an apparent increase in size, presents no gross pathology. In less than one-tenth of the cases its surface is stippled with minute abscesses. A perisplenitis gives a dull grayish color to the capsule, which may adhere to the surrounding structures.

Reproductive Organs. The chief change in the reproductive organs is hemorrhagic. The blood vessels of the testes and ovaries show dilation, congestion, and at times hemorrhage. In a few instances small abscesses similar to those in the kidneys are present in the testes, but they are uncommon in the ovaries.

Intestine. Congestion of the hind gut with distention of the blood vessels is a common finding, but this condition is frequently observed in other diseases.

Symptomatology

There are no characteristic symptoms other than the objective ex ternal lesions. The general appearance of the trout is good. Fungus is infrequent except during the period of greatest mortality. There is a darkening of the natural color, such as occurs in debilitating diseases, which gives to the rainbow trout a peculiar blue-gray appearance. The diseased trout are less active than the well, less responsive to stimuli and frequent the protecting sides of the pools. The presence of the disease is chiefly indicated by the daily losses.

Etiology

The etiology of the disease is still undetermined. All evidence points to an infection of bacterial origin, although it is impossible to state whether the infection is primary or secondary.

Bacteria. Smear examination of the purulent material from the abscess lesions in kidneys and muscles and the pericardial effusions showed enormous numbers of bacteria. These organisms were small short Gram-positive diplo-bacilli, slightly less than one micron in length, and morphologically unlike the extraneous bacteria usually found in dead fish. The same organisms were also obtained from the apparently unaffected liver, spleen, and blood. The great number which were present in the lesions, blood, and viscera suggests that this organism is the probable cause of the inflammatory lesions.

Cultures. Cultural methods gave discouraging results. Nearly all cultures resulted in no growth or showed the presence of contaminants. Aerobic and anaerobic methods with several types of special

enrichment media were tried without appreciable results. Four cultures of an organism which resembled the bacteria present in the smears were finally obtained. Delicate, slowly growing, slightly opalescent colonies appeared on hormone agar at room temperature after two days. Better growth was obtained with subcultures, but the organism still retained its delicate characteristics.

Inasmuch as the etiologic role of this bacterium has not been definitely established, only a brief description of its cultural characteristics is given. It is a Gram-positive, non-acid-fast, non-capsulated motile bacillus, one to four microns in length. The optimum temperature for growth is 22° to 26° C. Growth occurs at 37° C. but is feeble and abnormal. On meat infusion agar, small round convex slightly opalescent colonies of a light amber color develop, reaching a size of 0.1 mm. in 24 hours and 0.5 mm. in 48 hours. Growth on meat extract agar is slow and slight. On defibrinated blood agar the colonies are raised, gray, glistening, and non-hemolytic. In meat infusion broth a slight cloudiness is observed at 6 hours which becomes marked at 24 hours, and at 48 hours a white precipitate occurs without pellicle formation.

The four isolated strains resembled each other in all cultural characteristics and their serologic identity was established by cross-agglutination and agglutinin absorption with immune sera. Slight differences were found in their fermentation of carbohydrates, which occurred without gas formation. All four strains fermented dextrose, dextrin, levulose, mannose, maltose, salicin, and sucrose and did not ferment adonite, arabinose, dulcitol, quercit, rhamnose, sorbitol, and xylose. Strains number 54 and number 102 fermented galactose, inulin, lactose, and mannitol, which were not fermented by Strains number 58 and number 90. Strain number 54 fermented inositol and raffinose, which were not fermented by the other three strains. Barring these variations in carbohydrate fermentation, which often occur in closely allied varieties, these four strains are culturally and serologically identical.

Experimental Infections. Results of experimental infections were disappointing. Ten healthy brook trout which were inoculated intramuscularly with the purulent material from the kidney abscesses of diseased fish died in 18 to 25 days. All showed necrosis of the muscle along the line of inoculation. One had an excess of fluid in the peritoneum and two showed mottling of the kidneys but no abscesses. Bacilli similar to those in the injected material from the diseased trout were obtained in smears from the various organs: Kidney, 100 per cent; liver, 90 per cent; spleen, 90 per cent; and heart blood, 70 per cent.

Twenty healthy brook trout, which were held in an aquarium at a water temperature below 40° F., were injected intramuscularly with saline suspensions of cultures number 58 and number 90. Death occurred from thirty-three to sixty-four days, the average being about

forty-seven days. The needle wounds had healed, leaving no external marks, but beneath the skin there was a dark red streak in the muscle. In one trout two small white hard areas were present in the kidney; in two the kidney was badly congested; and in two the hind gut was injected. Smears showed the presence of the bacilli at the site of inoculation in five cases, and in the heart blood in one case. Cultures of the injected organisms were obtained in four cases from the site of inoculation.

Epidemiology

Mortality. The average monthly losses in per cent for adult brook and rainbow trout from 1929 to 1935 are given in the following table:

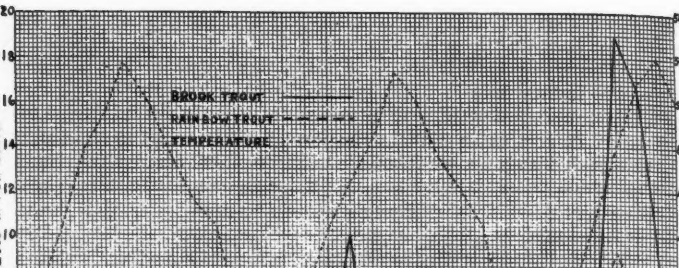
Average Monthly Per Cent Mortality in Adult Trout

Year	Brook Trout	Rainbow Trout	Average
1929	0.3	0.0	0.2
1930	0.7	0.8	0.8
1931	1.4	1.7	1.6
1932	3.4	0.5	2.0
1933	3.2	0.6	1.9
1934	6.0	1.4	3.7
1935*	7.4	4.3	5.8

*First half year.

Normally the losses in the adult and yearling brook and rainbow trout do not average more than one per cent per month. In 1932 there was a rise in the mortality in the adult brook trout which persisted in 1933 and increased markedly in 1934 and 1935. In the rainbow trout and in the yearling brook trout the losses were not remarkable until 1934. No excessive losses were observed in the fry or fingerlings. It is possible that the disease may have first appeared among the adult brook trout as early as 1932, but was not recognized until it attained serious proportions in 1934.

Season. The accompanying chart shows the monthly loss during the period 1933 to 1935 for adult brook and rainbow trout. It illustrates the probable early onset in the brook trout, the more definite manifestations in 1934 and 1935, and the lower mortality of the rainbow trout. The seasonal character of the disease is definitely indicated. Mortality is confined to spring and early summer and does not follow absolutely the curve of water temperature. The rise in mortality begins when the water temperature reaches 44° F. Its peak does not coincide with the height of the temperature curve, being about two months earlier, May vs. July. By September the loss has fallen to a stable level, slightly over two per cent, when the water temperature is still as high as 49.5° F.



Monthly Loss (Per Cent) Brook and Rainbow Trout, 1933-1935.

Distribution. As far as is known the disease is essentially a hatchery disease. Diseased trout have been found in the waters connected with these hatcheries, but they probably were escaped hatchery fish. A diseased wild trout has been taken in western Massachusetts, but it may have been from planted hatchery stock. Experiments relative to the transmission and the methods of control of the disease have not as yet been carried out.

Discussion

Etiology. It is difficult to designate the primary etiologic factor in this disease. Two conditions may give the same end picture: (1) a primary non-infectious metabolic disease with a possible nutritional background, producing pathologic changes in the chemical and physical constituents of the body fluids, which result in general anasarca, with a superimposed secondary infection, and (2) a general infection with selective affinity for the kidney, producing renal insufficiency with its corresponding train of symptoms. At the present time it is impossible to determine definitely which is the primary condition. The evidence suggests that we are dealing with a chronic infectious disease of bacterial origin with a selective affinity for the kidney and that the complex pathology is the result of impaired renal function. In the majority of cases the pathologic findings indicate a definite infection, as evidenced by the purulent nature of the abscesses and the inflammation of the serous cavities. Smears from the lesions, organs, and blood show the presence of numerous small Gram-

positive bacilli. The great number of these organisms, their presence in all the local lesions, and in the blood, liver, and spleen, in spite of unsatisfactory cultural results and inconclusive experimental infections, point definitely to a bacterial infection.

The earliest and most numerous lesions are found in the kidneys, which exhibit all stages of chronic, healing, and acute infection. Renal insufficiency as a result of impaired kidney function from an infectious nephritis could produce sufficient anasarca to give the typical objective symptoms of ascites, pericardial effusion, and exophthalmos.

The mortality rate is seasonal and to some degree follows the curve of the water temperature, in this respect resembling bacterial infections, in which the greatest losses usually occur during the period of high water temperatures However, this fact would not differentiate between a primary and secondary infection.

In 1934 prophylactic treatment by diet was tried without avail, when the etiology of the disease was first believed to be of a metabolic nature. The cod-liver oil treatment recommended by Davis (1934) for kidney disease, characterized by popeye and ascites, was tried. Three per cent cod-liver oil, iodine, clam meal, and other vitamin additions in the form of green vegetation were conscientiously administered for many months with no favorable results. It would seem that some other factor than diet was involved.

Resistance. The extent and variety of the lesions depend upon the age, vitality, and resistance of the trout. As a rule the larger and more resistant trout have the more extensive lesions. The disease is chronic and does not manifest itself early in life.

The rainbow trout, which are more resistant than the brook trout, have a lower mortality and show more extensive superficial blebs. Infection seems to occur earlier and spread more rapidly in the brook trout, which show more marked internal lesions, greater vascular engorgement, and more purulent lesions than the rainbow trout.

Summary

1. A preliminary report on a heretofore undescribed disease of the Salmonidae is made.

2. At present the disease is limited to hatchery fish.

3. The pathologic findings indicate that it is a chronic infectious disease.

4. The etiology has not been definitely determined. Apparently the etiologic agent is a bacterium, which is difficult to cultivate. Koch's postulates have not been confirmed, since the typical disease as yet has not been produced by inocculation with cultures.

5. It is impossible to state definitely whether the bacterial infection is primary or superimposed upon an already existent metabolic disease. The final pathologic picture is that of an infection.

6. The chief pathologic features are (1) serous effusion and empyema in the serus cavities, especially the pericardium and peritoneum, (2) multiple abscesses in the kidney, and less frequently in the liver, spleen, and reproductive

organs, (3) local edema and abscesses of superficial and deep tissues, (4) exophthalmos, and (5) vascular changes of a hemorrhagic nature.

7. The kidney is the chief organ affected. The metabolic disturbances are the result of impaired kidney function or of chemical or physical changes in the body fluid.

8. The mortality is seasonal and is associated with warm water temperature, but the earlier peak of the mortality curve does not absolutely coincide with the temperature curve.

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A WESTERN TYPE OF BACTERIAL GILL DISEASE*

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The first reference to a pathological condition of the gill tissues of salmonid fishes was made by Osburn in 1910. This author in describing a progressive infolding of the opercula of trout, commonly known to hatcherymen as "short gill covers," mentioned a marked proliferation on the gill epithelium as accompanying this condition. Osburn assumed that the club-like appearance of the gill filaments due to the proliferated epithelium was the result of continual irritation of the delicate gill tissue in the absence of the usual protection offered by the normal opercula. Although such a conclusion seems quite logical, it is also possible that Osburn was dealing with "short gill covers" complicated by the unknown bacterial gill disease which was subsequently described by Davis.

Davis, in his descripttion of bacterial gill disease, states the causative organism to be a characteristic, but undescribed, filamentous rod shaped bacterium which is usually found in great abundance in typical cases of the disease. This organism is not a tissue invader and its chief damage to the host lies in the irritation produced by the surface growth on the delicate gill epithelium. As a result of this irritation, the gill epithelium responds by a marked multiplication of the cells. As the infection persists, the gill filaments assume the club-like appearance described by Osburn and in advance cases, a complete fusion of the filaments may be found. The thickened gill epithelium not only impedes the vital exchange of oxygen and carbon dioxide between the water and the blood streams, but the actual area of respiratory surface is markedly reduced by the epithelial cells completely overgrowing the lamelli of the gill filaments. The club-like appearance and fusion of the gill filaments are often regarded as specific characteristics of bacterial gill disease.

During the past year, severe losses were experienced at certain trout hatcheries in Montana, Washington, and Oregon from a gill infection which differs in some respects from the typical bacterial gill disease. The lesions of this western type of gill disease are, so far as known, similar to those of bacterial gill disease as described by Davis although in no case has the typical and characteristic causative organism of the latter been found. Intensive search of heavily infected gill tissue taken from fish which have received no form of treatment has, in no instance, revealed the presence of the characteristic bacterium which is to be found with relative ease in similar cases of the eastern gill disease. Furthermore, unlike the eastern gill disease, the western variety fails to respond favorably to any of the customary methods of treatment. Hence, it is concluded that more than one organism may be

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capable of producing lesions hithterto believed specific for bacterial gill disease.

Stained smears of heavily infected gill tissue show two organisms to be commonly present. One, a Gram negative rod measuring 1.6—4.8 μ in length by 0.25 μ in width. This organism superficially resembles the causative agent of eastern gill disease although it is apparently but seldom found in chains of more than two organisms. The second, and more common, organism present is likewise a Gram negative rod measuring 1.6—4.0 μ in length by 0.5 μ in width. This organism is often arranged in pairs. Which one, if either, of these organisms is responsible for the western type of gill disease is not known.

The histo-pathological progress of the western type of gill disease appears to be similar to that of the eastern type, although the latter has never been described in detail, hence direct comparison is impossible at the present time.

The western type of the disease appears at the distal end of the gill filaments and often among those filaments located along the outer curve of the gill arch. Plate 1 pictures a section of normal gill tissue taken from a one and one half inch brook trout. The lamellæ are little more than capillary arches covered by an extremely delicate layer of flattened epithelial cells. As shown by this plate, in the normal gill the blood stream is separated from the circulating water by the endothelium of the capillary and one layer of simple squamous epithelium. Plate 2 shows an early stage in the western type of gill disease. The epithelium along the longitudinal axis of the filament, as well as that of the lamellæ, is actively proliferating. Four of the lamellæ on the filament to the left in this plate have been fused together along the distal margin by the rapidly multiplying epithelial cells. Plate 3 figures a more advanced stage in the disease. The interlamellar spaces of the filaments are practically filled by blocks of solid epithelial tissue, hence the greater part of the respiratory surface of the lamellæ is completedly blanketed. Plate 4 shows an extreme stage in this disease. The lamellæ are entirely overgrown and the epithelium of one filament is completely fused with that of a bordering filament.

No method of treatment which has been employed to date, including salting; hand dipping in a 1 to 2,000 solution of copper sulphate; and prolonged dippings in copper sulphate 1 to 200,000, 1-300,000; potassium permanganate, 1-250,000, 1-400,000; and sodium dichromate, 1-100,000 has proven of marked benefit. Of these methods, hand dipping in copper sulphate and prolonged dipping in potassium permanganate 1-250,000 have shown some promise. Neither method, however, offers even a satisfactory cure, for losses subsequent to treatment of experimental lots of infected fish with these methods were but little less than the losses among the untreated controls.

It is believed that the western type of gill disease progresses rela-

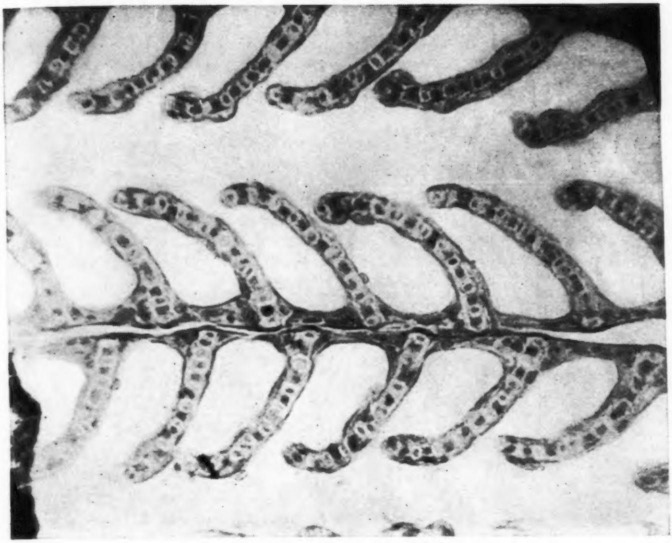

Plate 1.—Normal Gill Structure
Section of gill from 1½-inch brook trout, Hematoxylin and eosin, X45.

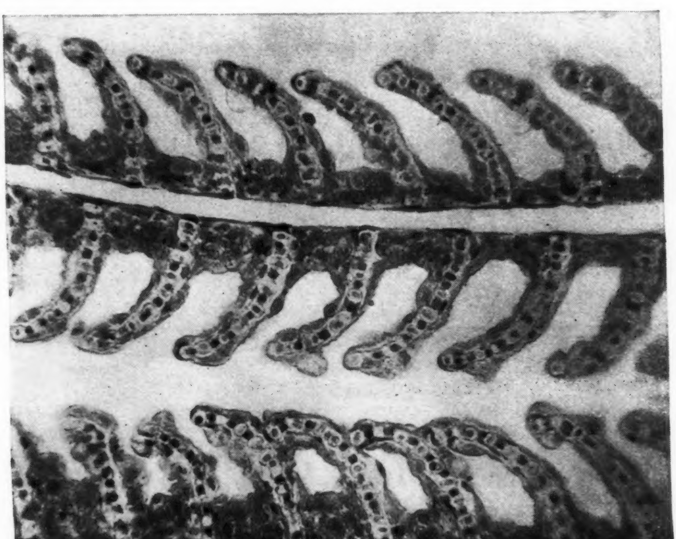

Plate 2.—Pathology of Early Stage of Gill Disease
Note the thickening of the epithelium along the filament and the lamellæ. Fusion of four lamellæ apparent on filament to left. Section of gill from 1½-inch brook trout, Hematoxylin and eosin, X45.

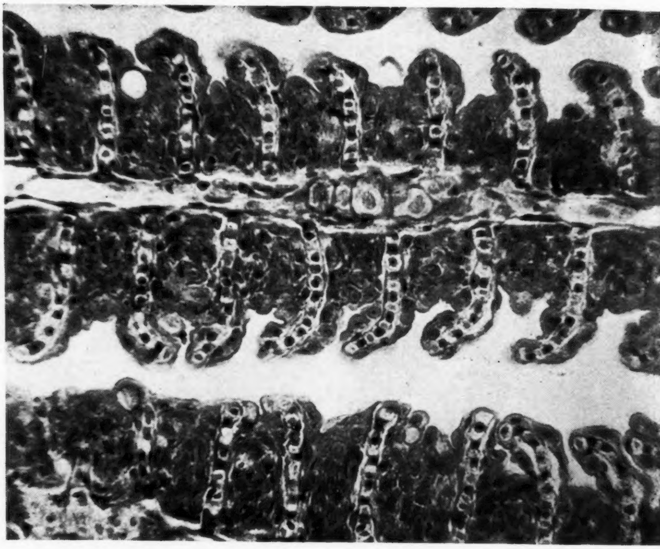

Plate 3.—Pathology of Advanced Stage of Gill Disease

Note the increasing amount of epithelial tissue between the lamellæ and the consequent reduction in the area of respiratory surface. Section of gill from 1½-inch brook trout, Hematoxylin and eosin, X45.

Plate 4.—Pathology of Extreme Stage of Gill Disease

Note the complete overgrowth of lamellæ and the fusion of two filaments. Hematoxylin and eosin, X45.

tively slowly in a subpatent condition, during which period marked tissue alteration occurs. By the time it is realized that this disease is present, the gills are so altered that the fish are unable to withstand the additional rigors of treatment. Prophylactic treatments, when and if such measures are perfected, furnish the most promising method for combatting this disease in the hatcheries.

Summary

A new type of bacterial gill disease common in hatcheries in the Western part of the United States is described. The lesions are apparently comparable to those of the eastern bacterial gill disease described by Davis, although the causative organisms appear to be distinctly different. Although the eastern type of gill disease responds readily and favorably to hand dipping in copper sulphate solution or to chlorination, the advisability for administering any known form of treatment to the western type is not so apparent. The progressive pathology of the western type of gill disease is described.

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THE USE OF POTASSIUM PERMANGANATE IN THE CONTROL OF FISH PARASITES

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The medicine cabinet of the fish culturist greatly resembles the well known cupboard of old Mother Hubbard. It is almost bare. On one shelf are to be found a few disinfectants—mostly of questionable value; on another repose copper sulphate and perhaps potassium permanganate—whose presence rests largely upon the sort of evidence one finds in the more honest patent medicine testimonials; and along side of the cabinet, too large to be stowed away inside, stands a whole barrel of salt. Many medicines have been tried, but few accepted. Even in the case of the few which have found a measure of use one finds in the literature pitifully little in the way of experimental data regarding their action. Instead one finds, as stated, testimonials.

It is the purpose of this paper to present all the available evidence for the use of one "fish remedy"—potassium permanganate. First its use in human medicine will be discussed, then its use in treating fish diseases, and finally the results of some experiments the author has conducted during the past year will be presented.

Use of Potassium Permanganate in Human Medicine*

Potassium permanganate, in consequence of the facility with which it imparts oxygen to almost all organic matter, is one of the most powerful oxidizing agents known. When the germicidal power of a disinfectant is to be rated this is usually done by comparing its power to that of phenol. In the absence of organic matter potassium permanganate is found to be distinctly superior to phenol, but it is so readily decomposed that in the presence of pus or other albuminous matters it is almost inert. It has found considerable use as a cleanser of wounds, is used in the treatment of fetid ulcers, abscesses, carbuncles, and of fetid discharge from the mucous membranes. As a local stimulant it has been used in chronic and indolent ulcers.

As an external disinfectant it is generally employed in strengths varying from 1 to 5 per cent, but for application to mucous surfaces its strength must be greatly reduced, and it may be employed in strengths of from one part in 2,000 and upwards.

Its use as an antidote for snake bite is well known. It is generally injected hypodermically into the region of the bite in strengths of from one to two per cent. It probably destroys the poison through its oxidizing influence.

*This discussion is taken from the U. S. Dispensatory, and Cushney's Pharmacology and Therapeutics.

In a salve it has been used to stop the flow of blood, which it probably does through its astringent action.

One per cent solutions have been found to be of value in treating poison ivy. Concentrated solutions irritate and even corrode the skin.

Use of Potassium Permanganate in Treating Fish Diseases

Owing to lack of library facilities I have not been able to determine who first used potassium permanganate in the fight against fish diseases. By 1904, when Hofer published his Handbuch der Fischkrankheiten, it had already found some application in Germany, and Hofer cites an article by E. Albrecht on this subject which appeared in 1898 (See bibliography). It was apparently not used for any of the bacterial diseases, for Hofer describes fourteen such without suggesting remedies for any of them other than preventive disinfection of ponds with slaked lime. Under his discussion of Saprolegnia, however, he has the following to say:

"Of all these remedies I can best recommend . . . potassium permanganate as being the most suitable. It is best to carry out the treatment of fungused fish in such a manner that first a small quantity of strong, about 1 per cent, solution of potassium permanganate is prepared and the fungus rubbed off of the fish by means of a sponge dipped into the solution. Of course this treatment does not affect the fungus threads of the skin which remain capable of reproducing. The washing must therefore be followed by a bath in a solution of potassium permanganate (1 part of the permanganate to 100,000 parts of water . . .). In this solution one can place salmonids and cyprinids for half an hour without injury. The solution then penetrates through the previously torn-off ends of the fungus threads into the depths of the skin and kills the fungus without any lasting injury to the fish. During the bath the fish must be carefully watched and the water aerated because there are deposited on the gills of the fish fine granules of manganese dioxide from the potassium permanganate, through which the breathing of the fish is greatly hindered."

Hofer further warns that if great numbers of fish are to be treated the solution will have to be renewed frequently as it soon loses its strength through action on the skin of the fish.

Hofer makes one other reference to the use of potassium permanganate when he discusses means of combatting Gyrodactylus. His statement concerning the use of another remedy is here also included because of its bearing on the now widely used acetic acid treatment. Concerning Gyrodactylus Hofer says:

"As such (remedies) are to be highly recommended ¼ per cent solutions of salicylic acid. Herein the fish are kept, under careful observation, for one-half hour, after which time the parasites in the skin are killed. Furthermore potassium permanganate, used in a solution of 1:000,000, also works quite well, the method being the same as was recommended for killing fungus."

Plehn, in 1924, advocates potassium permanganate for saprolegmia and follows the method given by Hofer for its use. She further recommends it for disinfecting ponds where fish are suffering from Furunculosis. In that connection she states that a solution of 1:150,000 for one hour will kill *Bacterium salmonicida* without injuring the fish. If no fish are present in the pond a 1:100,000 solution is to be used. Of course, she does not state that this is a cure for Furunculosis—merely a method of disinfection.

Plehn does not mention potassium permanganate for use against Gyrodactylus.

American fish culturists have been slow to adopt potassium permanganate. America's foremost authority on fish diseases, Dr. H. S. Davis, in the 1929 edition of "Care and Disease of Trout" mentions the compound only twice: once in connection with Furunculosis, and again in connection with fungus disease. His references are merely statements to the effect that German fish-culturists use it for these diseases. He himself makes no recommendation.

In 1930 Walter N. Hess published the results of numerous large scale experiments in the use of potassium permanganate for controling external fluke parasites. In his tank experiments Hess found that a two hour immersion in a 1:267,000 solution rid gold fish of flukes without injuring the fish. For a quick dip Hess found that from one and one-half to two minutes in a 1:2,000 solution was more effective than the commonly used acid dip. In ponds Hess found that because of differences in the amount of organic matter present it was more difficult to determine the correct dosage. He was able, in most cases, to exterminate the flukes with two-hour treatments ranging between 1:330,000 and 1:200,000. The weaker solutions were used on smaller fish. Occasionally the treatments had to be repeated after 7 to 10 days. Hess found that it required a slightly greater concentration of the permanganate to kill flukes of the genus Dactylogyrus than those of the genus Gyrodactylus.

In 1932 Kingsbury and Embody published some results on the use of potassium permanganate. Since their article was summarized by Prevost in Vol. 64 of the Transactions of the American Fisheries Society it will not be necessary to dwell upon it here. Suffice it to say that they recommend one-hour treatments in from 1:75,000 to 1:250,000 solutions, depending on the temperature and the size of the fish. The strongest solution (1:75,000) they recommend chiefly for ridding mature trout of Gyrodactylus in winter when the water temperatures are below 40° F. One hour treatments in concentrations of 1:150,000 to 1:100,000 they claimed to be effective in the elimination of Gyrodactylus, Chilodon, Cyclochaeta, gill bacteria, and Dactylogyrus (on goldfish).

In the 1934 edition of "Care and Diseases of Trout" Davis cites the work of Kingsbury and Embody, but otherwise makes no change from his earlier edition. Apparently the fish culturists of the Federal

Bureau of Fisheries have not found much use for the substance.

In the 1934 Transactions of the American Fisheries Society Prevost reported on half-hour treatments with a 1:300,000 solution of potassium permanganate carried on throughout the summer in two different Canadian fish hatcheries. In one of these the treated fish were stunted as compared with the untreated check—both lots coming from the same eggs. In the other hatchery no such stunting took place. There was also a greater mortality in the treated lot in the first hatchery but not in the second. The hatchery in which the permanganate had a bad effect both as to growth and mortality was one where the water was low in organic matter. In the hatchery where the permanganate had no effect whatever on either growth or mortality the organic content of the water was higher. Prevost's explanation is that in one case the presence of organic matter in the water protected the fish from the effects of the permanganate. In the other case, less organic matter being present, the fish felt the full force of the permanganate, and that under these circumstances a half-hour treatment in a 1:300,000 solution at a temperature between 50° and 55° F. proved injurious. While the theory behind this explanation is probably correct it must be noted that neither Kingsbury and Embody, nor Hess, had any trouble with so weak a solution as 1:300,000 used for so short a time as half an hour. Prevost's case would be more convincing if we were given more of the details of the experiment. We do not know, for instance, whether he had 100 fish in each of the experimental lots, or 10,000.

Original Experiments

During the autumn of 1934 an epidemic of Gyrodactylus occurred among the fish at the Johnstown, N. Y., Hatchery. The fish affected were all brook trout averaging between five and six inches in length. All the fish at the hatchery became infected, although for a long time only the lowermost ponds of the two series wherein the fish were kept showed any great losses. All the fish were in ponds, and all the treatments except the acetic acid dip took place directly in the ponds. There were two series of four ponds each at this hatchery, one stream of water flowing through ponds I to IV and another stream from the same source flowing through ponds V to VIII. The rate of flow through the ponds could be measured quite accurately because, in consequence of a difference in level, a tub could be inserted between two of the ponds of each series and the entire flow caught in the tub. By timing the filling of the tub, whose volume was known, the rate of flow could be estimated. This measuring of the flow through the ponds was repeated several times before each experiment.

The chemical solutions were introduced into the ponds by means of a floating siphon adjusted to deliver the required quantity of the solution during the course of an hour. The flow of water through the ponds therefore did not have to be stopped during the treatments.

The average daily mortality of the entire 30,000 fish at the hatchery for the three weeks immediately preceding the experiments is given in the following table:

Daily mortality, November 1- 7	59 fish
Daily mortality, November 8-14	89 fish
Daily mortality, November 15-21	124 fish

From the time the disease was first noticed, early in October, to the time the experiments were started (Nov. 21) the fish had been given six treatments with a very weak solution of potassium permanganate—one part of the chemical to 175,000 parts of water. The treatments had been administered by the siphon method and the duration of the treatments was one hour. There was no indication that the treatments had done any good, although we cannot be certain of this for no pond was left untreated as a check. The mortality figures given above show that the effects of the infestation were steadily becoming more pronounced.

On November twenty-first the experiments herein recorded were begun. Since it became necessary to examine great numbers of fish during the course of activities, and since a complete examination of each fish consumed too much time, it was decided to examine only the four paired fins of each specimen. Contrary to Davis' statement that the dorsal and caudal fins are especially liable to infestation (Care and Diseases, 1934, p. 29) the fish at the Johnstown Hatchery seemed to have their pectorals and pelvics most heavily inhabited by the worms. These fins were therefore cut from the fish and examined with a low powered binocular microscope. In most cases the Gyros were counted. It must be remembered, therefore, that all figures given in the following pages refer to the number of worms on the paired fins, not on the whole fish.

On the morning of November twentieth fish from each pond were examined. Every fish showed parasites. In some cases a single fin showed as many as fifty of the active squirming worms on it.

Experiment I. Acetic Acid

On the afternoon of November Twentieth the 5,000 fish in ponds VII and VIII were removed, and the ponds treated with chlorinated lime. This disinfectant was allowed to remain in the ponds over night. The next morning they were drained and refilled with fresh water.

The 5,000 fish previously removed were now given a one-minute dip in 1:500 acetic acid. They were dipped one net-full at a time, more acid being added from time to time to keep up the strength of the solution. Entirely fresh solutions were made after each half dozen net-fulls.

Only fifteen fish died as a result of the treatment. Six of these were examined for Gyros. A few were found on each of the fish, but their numbers had certainly been greatly reduced by the dip. Even those still found adhering to the fish appeared to be dead. No amount of

prodding with a dissecting needle could evoke any reaction from them. They could be scraped off quite easily, which is not the case with normal Gyros.

On November twenty-second, two days after the acid dip, some of the fish were again examined. Of six fish one showed none of the worms, four were lightly infested, and one was swarming with the organisms. Apparently the worms had recovered, at least in part, from the dip.

The conclusions drawn from these latter observations are that under the conditions of the experiment a one-minute dip in 1:500 acetic acid will kill a majority, but by no means all, of the Gyros on infested fish. Gyros which appear to be dead immediately after the treatment are capable of reviving and continuing an active existence on their hosts.

The temperature of the water during these treatments was 42° F.

Experiment II. Potassium Permanganate

Since one-hour treatments with 1:175,000 permanganate had not been effective, and since dipping all the fish in acid and then sterilizing the ponds was impracticable, it was decided to continue the experiments with the $KMnO_4$ baths. The procedure was to make up a solution of permanganate of such strength that when siphoned into the upper end of a pond the resulting flow through the pond would be of the desired strength. All treatments lasted one hour. Since the water temperature varied from day to day it will be given for each experiment separately.

One pond full of fish was given a one-hour dose of 1:125,000 permanganate. The water temperature was 42° F. The fish showed no signs of distress.

Examination of the fish immediately after the treatment showed plenty of active Gyros. Another examination twenty-four hours later gave the same results. This treatment had clearly not been strong enough to kill the parasites.

Experiment III.

A few days later the fish in pondss I-IV were given a one-hour bath in 1:110,000 permanganate. The water temperature was 39° F.

Fish from each pond were examined shortly after the treatment. Of sixteen fish examined only four were entirely free from the parasites. All the rest showed living Gyros, four of them being very heavily infested.

Experiment IV.

On the same day that the above experiment was performed ponds V-VIII were given a one-hour dose of 1:100,000 permanganate. The water temperature was again 39° F.

Eight fish were examined about four hours after the termination of

the bath. Of these two showed no Gyros, while four of the remaining six were heavily infested.

Experiment V.

A week after the above treatments had been administered ponds I-IV were given an hour of 1:90,000 $KMnO_4$. The temperature of the water was 42° F. Fish from all four ponds were examined previous to the treatment, and plenty of Gyros were found.

An examination shortly after the treatment gave the following results:

No. of Fish	No. of Gyros Per Fish
23	0
8	1
3	5-10

The next morning fish from these ponds were examined again to see whether the Gyros might have recovered over night. The findings were as follows:

No. of Fish	No. of Gyros Per Fish
5	0
6	1
1	18

This did not indicate any particular recovery on the part of the Gyros. It thus appears that at 42° F. a 1:90,000 solution of $KMnO_4$ used for one hour will kill a majority of the Gyros present. But it will not by any means exterminate them.

The fish showed little signs of distress during this treatment, and in only one of the ponds did any considerable mortality occur. In the most heavily infested pond fifty-three fish died out of a possible 2,500. These were all fungused fish which would probably have died anyway.

Experiment VI.

It was decided to try a slightly stronger solution than the one given above to see if the Gyros could not be completely exterminated. As it appeared dangerous to strengthen it very much a solution of 1:85,000 was decided upon. The temperature of the water was 42° F.

Fish in ponds V-VIII were examined previous to the treatment with the following results:

No. of Fish	No. of Gyros Per Fish
1	0
5	1-5
3	6-10
2	11-20
3	75-100

Examination immediately after the treatment gave the following results:

No. of Fish	No. of Gyros Per Fish
7	0
2	1-5
1	10
1	14
4	25-50
1	70

From these figures it appeared that the 1:85,000 solution had not been as effective as the 1:90,000. At first it was thought that the calculations for the rate of flow of the water through the ponds had been incorrect, and that contrary to intentions the second solution had really been weaker than the first. This assumption was borne out by the fact that out of the 14,000 fish given the 1:90,000 treatment seventy-eight had died, whereas of the approximately same number given the 1:85,000 only fourteen had died.

Another explanation presented itself, however. The fish in Experiment VI had been examined immediately after the trmination of the treatment, whereas in Experiment V the examination had not been started until about an hour after the termination. In Experiment VI all of the first fish examined had Gyros, while as the examination progressed more and more were found without them. Thus four fish from pond V, examined immediately after the treatment, had an average of twenty-two active Gyros each. This was the first pond of the series and the one into which the solution had been introduced directly. It should therefore have had the strongest dose. One would expect a part of the permanganate to have been reduced by the time it reached pond VIII. Yet of five fish examined from pond VIII not one of them had any Gyros. This made it appear that the permanganate might have a somewhat delayed effect, and that fish should not be examined until some time after a treatment is given if one expects to discover the real effect of the solution.

To check this possibility it was decided to return to pond V again to examine another sample of fish. This second examination took place some four hours after the first.

Five fish were examined this time. Four were entirely free from Gyros while one had two of the organisms. Comparing these results with the results of the first examination where four of the fish had averaged twenty-two Gyros each it can be seen that there was good reason to suppose that the permanganate, in the strength here used, was effective, but that its effects did not immediately become apparent.

Since the fewer deaths of fish in Experiment VI than in Experiment V might have been due to the fish in ponds V-VIII being in somewhat better condition than those in ponds I-IV, I assume that my calculations for the solutions used were correct.

As a further check, the next morning (twenty hours after the termination of the treatment) seven more fish were examined from pond V. The results follow:

No. of Fish	No. of Gyros Per Fish
2	0
3	1-5
2	8

Thus the indications were that a 1:85,000 solution killed many but not all of the Gyros.

Experiment VII.

A week later ponds I-IV were given a 1:75,000 treatment. The duration of the treatment was one hour, and the water temperature was 34° F. Examination of fish previous to the bath gave the following results:

No. of Fish	No. of Gyros Per Fish
3	0
6	1-5
1	9
1	40
1	53

In order to give the Gyros plenty of time to show the effects of the permanganate examination of the fish was delayed until the day after the treatment. Results of this examination were:

No. of Fish	No. of Gyros Per Fish
16	0
2	1

Since the 1:75,000 permanganate had apparently been so effective the same treatment was administered to ponds V-VIII on the next day. The water temperature this time was 38° F. Examination of the fish previous to the treatment gave the following results:

No. of Fish	No. of Gyros Per Fish
3	0
6	1-5
1	10
1	25
1	27

Examination twenty hours after treatment showed Gyros present as follows:

No. of Fish	No. of Gyros Per Fish
16	0
2	1
1	2

In neither of these treatments did the fish show more than occasional symptoms of distress, and in neither case were more than a dozen fish killed.

Subsequent examination of the fish for a period of two weeks indicated that the Gyros were very scarce. During that time they showed no signs of coming back.

Conclusions from Experiments I-VII.

(1) At a water temperature of 34° to 38° F. a one-hour bath in potassium permanganate solution of 1:75,000 will kill most of the Gyrodactylus present on trout. Weaker solutions, even at temperatures up to 42° F., do not seem very effective.

(2) This strength solution was safe with the size fish here treated and in the particular water of this hatchery.

(3) The effect of the permanganate on the parasites is often not immediately apparent. Fish should be examined a day after treatment in order to determine the full effects.

(4) A one-minute dip in 1:1,500 acetic acid is not very effective in exterminating Gyrodactylus, as many of the organisms recover from the treatment.

Experiment VIII.

During the summer of 1934 a pond full of three-inch brook trout was given a treatment with a weak solution of potassium permanganate to see whether it would check a very mild case of fin rot with which these fish were afflicted. The treatment consisted of a forty-five minute bath in a 1:232,000 solution at a temperature of 45° F. which, according to all available information on the subject, should have been perfectly safe. Yet almost the whole pond full of fish died as a result of the treatment.

A number of the dead fish were examined microscopically and the only evidence of damage that could be seen was in the condition of the gills. These were uniformly clogged with slime and dirt, so much so that it must have been impossible for the fish to force much of a stream of water through them. The gills were carefully freed from the slime and dirt and examined under the microscope. This revealed no particular damage to the filaments beyond a somewhat swollen and congested condition which might have been due, not to any specific effect of the chemical, but to the fish being smothered to death by the accumulation of filth on their gills.

In order to test out the theory that the fish had been smothered by the accumulation of dirt and slime it was decided to investigate the effects of dirty water as compared with clean water in combination with potassium permanganate solution. These tests were conducted as follows:

Eleven gallons of $KMnO_4$ solution were prepared in a metal wash tub using pure clean spring water at a temperature of 45° F. Three-inch brook trout were placed in this solution for thirty minutes and

then removed to a trough of clean running spring water. Next a new $KMnO_4$ solution of the same strength was prepared, but in addition to the spring water a handful of mud and scum from the edge of a fish pond was introduced. After thirty minutes in this mixture the fish were placed for another thirty minutes in a tub full of similar dirty water but without any $KMnO_4$. This was done in order to more nearly approximate the conditions to which the fish in the pond had been subjected. They were then removed to a trough of clean running water and held for observation for forty-eight hours. The tabulated results follow:

Trial	Condition of Water	Strength of $KMnO_4$	Subsequent Treatment	No. of Fish	No. of Fish Died	Mortality after 18 Hrs.
1	Clean	1:100000	Clean wtr.	100	63	63%
2	Dirty	1:100000	Dirty wtr.	100	94	94%
3	Clean	1:150000	Clean wtr.	100	48	48%
4	Dirty	1:150000	Dirty wtr.	100	100	100%
5	Clean	1:200000	Clean wtr.	100	23	23%
6	Dirty	1:200000	Dirty wtr.	100	83	83%
7	Dirty		1 hr. dirty water	100	2	2%
8	Dirty	1:200000	30 min. in 1½% NaCl	50	39	78%

All experiments were conducted with water 45° F.

All treatments with permanganate were for thirty minutes.

The greater mortality in the dirty water as compared with the clean is a striking fact throughout the first six experiments. In every fish which died in the dirty water the gills were badly clogged, which made it appear that this clogging, and consequent smothering of the fish, is largely, and in the case of very weak solutions, perhaps entirely responsible for the death of the fish.

That the mud and dirt alone could not cause the death of the fish was almost a forgone conclusion in view of the fact that the ponds from which the fish came are quite muddy after every rain, and even when clear the fish are constantly passing through their gills the kind of foreign matter used in this experiment. To be perfectly certain on this point, however, experiment seven was performed. In this experiment the fish were held in the tub for one hour with approximately the same amount of dirt as had been used in the previous experiments. Only two out of the 100 fish died, and these deaths were probably due to injuries in handling.

In one way the addition of dirt ought to lessen the harmful effects of the $KMnO_4$, for the dirt contained a good deal of organic matter such as algae, protozoa, bacteria, nematodes, etc. The organic matter should have been acted upon by the permanganate and oxidized, thus weakening the solution and leaving less of the chemical to act upon the fish. Hess mentions this in his experiments on treating fish

in ponds, and Prevost emphasizes the matter particularly. In fact that is the whole point of his paper.

As a result of experiments one to seven the following theory was formulated. Potassium permanganate stimulates the secretion of slime both on the body and the gills of the fish. Irritating substances commonly have this effect, not only on fish but on the secretory cells of other animals such as frogs and toads. Perhaps it even alters the physical condition of the slime, making it more sticky. At any rate, particles suspended in the water adhere to the body of the fish and to its gills so that the fish becomes coated with dirt and its gills become very badly clogged. This condition causes the death of the fish by suffocation.

One more experiment was performed to find out whether the accumulation of dirt and slime could be removed by a salt water bath. Salt solution was used because it is commonly supposed to dissolve the slime of fish. Fifty fish (Experiment eight) were placed for thirty minutes in a 1:200,000 permanganate solution containing suspended matter. They were then held in a 1½ per cent salt soluttion for thirty minutes and thereafter placed in a trough of clean running water. Thirty-nine, or 78 per cent of these fish died. In the comparable experiment without subsequent salt treatment (Experiment six) 83 per cent had died. The salt solution, therefore, had practically no beneficial effect.

The conclusion to which these experiments point, namely, that in the presence of suspended matter, largely organic, a given solution of potassium permanganate is more harmful to fish than in the absence of such matter, seems to be directly the opposite of that reached by Prevost. Nevertheless it cannot be denied that Prevost's conclusion is perfectly logical. The contradiction seems to resolve itself into a question of whether a purely chemical explanation such as Prevost's, or whether a physiologico-physical explanation like the one here advanced is correct.

In the absence of more experimental data it would seem that both explanations might be correct. One might apply under one set of circumstances, and the other under another. For instance, in the case of very weak solutions such as Prevost used, organic matter in the water might reduce so much of the permanganate that not enough would be left to irritate the gills of the fish. In the case of stronger solutions, such as I used, reduction of permanganate by organic matter might still leave enough to irritate the gills thus causing excess production of slime which brings about a clogging of the gills and the suffocation of the fish.

At the time these experiments were performed the author was not familiar with the statements of Hofer regarding the use of permanganate. His observations regarding the deposit on the gills of the fish of fine granules of manganese dioxide and the consequent smothering of the fish are much to the point. (See quotation.) This doubtless

contributed to the effect of the accumulation of slime and trash described above.

In our efforts to treat fish with chemicals there is a danger in regarding the fish as simply a member of a chemical equation. The fish is a living object, not merely a chemical. In such treatments, therefore, it is well to cultivate a physiological point of view.

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Discussion

Dr. Hubbs: The conclusion is an extremely interesting one, that a chemical bath may stimulate secretion of mucus and therefore cause accumulation of dirt on the gills of the fish. Certainly those of us who have examined fish that have been treated in hatcheries have found a tremendous accumulation of this material on the gills. It is commonly stated that fish will be smothered by silt getting on their gills. I have never thought that a normal fish can be smothered by any amount of silt in the water, within any natural occurrence at least. I have seined fish out of water that was partly liquid mud, and found them in perfect condition. So that a normal healthy fish without any excessive mucous secretion is not likely to be smothered by silt in the water.

THE USE OF COPPER SULPHATE FOR ERADICATING THE PREDATORY FISH POPULATION OF A LAKE

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Various experiments and many practical observations indicate that the mortality of salmon trout fry, either naturally propagated or, artificially planted, is very high in many, if not most, of our lakes and streams (White, 1924, 1927, 1930; Foerster, 1929; Dahl, 1934). The problem of increasing the salmon and trout population of our waters, therefore, resolves itself to a considerable extent into developing a procedure of economically introducing larger fish, or one of improving the conditions for younger fish in the bodies of water concerned. The last method is principally one of eradicating the predatory fish, for it is they which determine to a large extent the survival of fish fry.

An experiment is being carried out by the Fish Culture Branch of the Canadian Department of Fisheries in an attempt to create a more suitable habitat in which to plant trout fry by eliminating the existing predatory fish population. Two lakes, Jesse and Hectanooga, Nova Scotia, have been selected for the purpose. Copper sulphate has been added to lake Jesse in sufficient amount to kill most of the fish. Upon the return of more or less suitable conditions, trout fry are to be planted in both lakes, Hectanooga serving as a control. The general results of adding copper sulphate to lake Jesse have already been discussed by Catt (1934). The purpose of this paper is to present more fully the course of events as they occurred in lake Jesse following the addition of the copper sulphate, and it may be considered complementary to Catt's account.

The use of copper sulphate for destroying obnoxious algae in municipal water supplies, and various other public waters, has been extensively applied throughout the country since the time Moore and Kellerman advocated the method in 1904. In certain instances fish have also been killed. Following this lead, Titcomb (1914) was probably the first to use copper sulphate for the purpose of intentionally killing undesirable fish. In 1913 he quite effectively destroyed the fish population (pike, pickerel, pike-perch, yellow perch, horned pouts) of Silver lake, Vermont, a lake of 65 acres, and apparently hard water, by adding 6,300 pounds of copper sulphate. Only a few pike survived the treatment.

The lake.—Lake Jesse covers an area of 45 acres. The maximum depth of water sounded is 21.5 feet (6.6 metres), with an average depth of eight feet (2.4 metres). The lake is situated on the Salmon river system, Yarmouth county, Nova Scotia.

The copper sulphate.—From a calculation of the volume of water in the lake, sufficient copper sulphate ($CuSO_4.5H_2O$) was added to give a concentration of 3.06 p.p.m., if the salt was evenly distributed.

The copper sulphate was added by towing the crystals in coarse sacks behind boats. The operation took place August 3, 1934, a day when the waters of the lake were thoroughly mixed by a strong wind. (The water was homothermous from surface to bottom at the time.) Additional details of the procedure have been given by Catt (1934).

A number of water samples were collected for analyses of the copper content. The analyses have been made by the Division of Chemistry, National Research Laboratories, Ottawa, Ontario. The results are presented in Table 1. The samples for August 3 were secured within an hour of the application, and those for August 4, 24 hours later.

The copper sulphate may have been removed from the lake Jesse waters by at least three means: (1) actual removal from the lake by the natural run-off, (2) removal from solution by combination with organic matter, (3) removal by precipitation with inorganic compounds. We will discuss each of these means separately.

(1) Removal by the natural run-off. On August 1 the run-off from the lake was estimated at about ten gallons per minute. However, before the copper sulphate was added this was completely stopped by a dam across the outlet, so it was some time before any water drained from the lake. Thus, the drainage removed little, or none, of the copper sulphate until fall, and after the autumnal rains. The drop in concentration of copper sulphate from an average of 1.90 p.p.m. on October 3 to 1.20 p.p.m. on December 6, and subsequent decreases in the surface water content (Table 1), was no doubt largely due to the increased drainage.

(2) Removal by combination with organic matter. It is usually conceded that organic materials in a body of water treated with copper sulphate remove considerable amounts of the salt from solution, depending upon the quantity of particulate and dissolved organic matter present at the time. Carroll (1904) found, in the treatment of a water supply at Butte, Montana, for algae, that a scum of *Anabaena* and other organisms contained 11¼ per cent metallic copper two hours after copper sulphate had been added. There were only small traces of copper in the water at the time, but the amount of sulphate had increased slightly. In this connection Smith (1905, p. 494) writes: "It seems probable that the copper is precipitated in albuminous combinations, that is, that it is absorbed by the albuminous constituents of the microscopic organisms in the water." Further he goes on to say that an absorption by precipitation or suspended albuminous matter is indicated by the fact that the dead organisms collected in treated reservoirs have been found to contain considerable quantities of copper. Thus, considering the dosage of copper sulphate necessary to eradicate algae in any particular body of water, Moore and Kellerman (1905) suggests that for each 10 p.p.m. of organic matter there should be a two per cent increase in the quantity of the salt added to the water.

However, in the removal of copper sulphate from solution by com-

bination with organic materials the question arises as to what types of combination can exist. Of proteins, Mathews (1921, p. 152) says: "A great deal of confusion exists in the literature on this subject of precipitation of proteins because of a failure to realize that these precipitates are true chemical compounds. The reactions are as a matter of fact almost certain simple salt formations." In the case of metals below hydrogen in the scale of solution tension, such as mercury, gold and copper, he goes on to say (p. 154): "These metals will not only form simple salts with the proteins by displacing the hydrogen from the carboxyl group, but they will also form addition compounds of double salts by union with the amino groups. It will be found, therefore, that mercuric chloride will precipitate even in a faintly acid medium, and so will the others of this group—(but) the precipitation is found to be more complete in a faintly alkaline than in a faintly acid medium." The determined pH value in the waters of lake Jesse varied from 6.2 to 6.6 (slightly acid in the chemical sense).

Birge and Juday (1922) found that crude protein made up in average about 55 per cent of the dry weight of certain phytoplanktonts, and about 53 per cent of the dry weight of certain zooplanktonts. However, the organic matter contained in the plankton is, on the average, only about 14 per cent of the total organic material contained in lake waters (Birge and Juday, 1927). In other words the dissolved organic matter content predominates. Of this dissolved organic matter, part consists of proteins and amino acids, which are usually more abundant at the bottom of lakes, particularly in stratified waters. Domogalla, Juday and Peterson (1925) found that the content of free amino nitrogen, for instance, in twelve Wisconsin lakes was in average about eighty milligrams per cubic foot of water, and Peterson, Fred and Domogalla (1925) have demonstrated the presence of the amino acids, tryptophane, tyrosine, histidine and cystine, in these waters. We are not aware of the organic matter content of the waters of lake Jesse, but from observations of the plankton content we are probably safe in assuming it to be of the order found in other lakes examined and reported upon.

From the foregoing discussion, therefore, it is possible to argue that the proteins and their derivatives, along with other organic substances, such as tannins, were responsible for the disappearance of about 2 p.p.m. of copper sulphate, the difference between the amount added (3.06 p.p.m.) and the amount determined in the water during the week after its addition (0.99 p.p.m. in average). This contention does not allow for precipitation of copper sulphate by inorganic compounds such as bicarbonates. This point will be discussed below.

The first samples for copper sulphate analyses were collected, as stated above, within a hour of the time that this chemical was added to the water. In Table 1 it is shown that the analyses of these samples gave about 1 p.p.m. of $CuSO_4.5H_2O$. That the results of these determinations should be so low is surprising, as one might well suppose

the water would contain at that time nearly all the copper sulphate added, since there was little time for the settling out of any organic or inorganic compounds which may have been formed. If in the water, combined or free, the copper would have been determinable. We are not in a position to explain the results, aside from indicating the possibility that 3.06 p.p.m. of copper sulphate was never realized in the water sampled, or the samples were incorrectly analysed.

(3) Removal by combination with inorganic salts. Ellms (1905) indicates that when copper sulphate is added to natural waters a basic copper carbonate ($CuCO_3.Cu(OH)_2$) may be formed, which hydrolyses to the copper hydrate and is precipitated. In alkaline waters this appears to be definitely the case. The above author found that in hard waters which he investigated the copper was entirely removed from solution by 24 hours. However, the basic copper carbonate is soluble in acid waters (Whipple, 1905). Thus, in lake Jesse water with its pH value of 6.3 (August 3), it is doubtful whether the basic copper carbonate could form. The fact that, in the presence of a large quantity of bicarbonate in proportion to the amount of copper added, all the copper was not removed from solution substantiates this argument.

In any case, it is known that copper may remain in solution for some time in acid waters. Smith (1924, p. 130) remarks: "Experience has shown that in ordinary or hard waters the copper sulphate is precipitated out within a few days, while in soft waters it may remain for some time." Even in hard water Ellms (1905) indicates that copper may be held in solution by certain organic materials, as those from a leaf infusion, for instance.

In table 1 it may be seen that there was a decided rise in the copper content of lake Jesse water from August 24 to September 15 (0.90 p.p.m. to 2.28 p.p.m. as $CuSO_4.5H_2O$). This indicates that there was, besides a retention of copper in solution, an addition to solution from some source, presumably from the precipitated forms. The retention of the copper left in solution after the initial precipitation is explainable through the acidity of the water and the meagre run-off from the lake, but for the increase in amount of copper in the water we can only make certain postulations, which may, or may not, be correct.

Ellms (1928, p. 476) writes: "A not infrequent result following the application of copper sulphate to a water supply infested with micro-organisms is the appearance of large numbers of bacteria. These are harmless forms of water bacteria that multiply rapidly, probably on account of the sudden increase in the food supply caused by the decomposition of the organic matter resulting from the killing of the micro-organisms." In this connection it was found that the number of bacteria increased from ten to twenty times in reservoirs at Greenwich, Connecticut, after treatment with copper sulphate (Moore and Kellerman, 1905). It is obvious that there would be an increase

in the amount of decomposable organic matter in the waters of lake Jesse after the copper sulphate was added. At first the numbers of bacteria were probably diminished owing to the toxic action of the copper, as demonstrated by Caird (1904). But given time (after the first week) the bacteria may have flourished in the lake Jesse waters, owing to the favorable temperature and food supply. It is here necessary to suppose that, upon the decomposition of the organic matter by bacteria, the copper held in combination was once again liberated. It is also necessary to suppose that the copper would be in a soluble form, either as inorganic or organic salt or salts, or both. If copper sulphate were again formed, it would, of course, be soluble, as would also a basic copper carbonate. The heavy metals such as silver and copper usually form insoluble compounds with protein substances in slightly acid or alkaline media, but certain soluble pharmaceutical compounds are known, such as a vitellin silver preparation (argyrol) and a copper-silver-albumin compound (cuprargol). Although questionable, compounds of this nature may also have been formed.

TABLE 1. COPPER SULPHATE ANALYSES OF LAKE JESSE WATER

Date	Location	Copper sulphate as p.p.m. of $CuSO_4.5H_2O$
August 3, 1934	Surface (open water)	1.10
August 3, 1934	Bottom (5.5 metres)	0.94
August 3, 1934	Composite sample from surface and bottom at various points	0.90
August 4, 1934	Surface (open water)	1.06
August 4, 1934	Bottom (5.5 metres)	0.90
August 4, 1934	Surface (at west shore)	1.06
August 8, 1934	Surface (open water)	0.94
August 8, 1934	Bottom (5.5 metres)	0.98
August 10, 1934	Surface (open water)	0.90
August 24, 1934	Surface (open water)	2.28
September 15, 1934	Surface (open water)	2.44
October 3, 1934	Surface (open water)	1.77
October 3, 1934	Bottom (5 metres)	2.13
December 6, 1934	Surface (open water)	1.20
March 20, 1935	Surface (open water through ice)	0.47
May 10, 1935	Surface (open water)	Trace (0.02)
May 10, 1935	Bottom (4.5 metres)	2.03

Physical and Chemical Conditions of the Water

Observations were made of the temperature, pH value, oxygen and bicarbonate contents of lake Jesse water. The results are given in table 2.

For the short period that the observations covered, following the addition of the copper sulphate, no appreciable effect of this treatment upon the various factors was disclosed. By killing the plankton more decomposable organic matter would be present in the lake, which matter as it decayed would lower the oxygen content and the pH value. The amount of oxygen determined on August 7 was the lowest encountered, but the decrease was not very significant. In this lake, at the time of treatment, the plankton was not decidedly rich, by no mean comparable to a "water-bloom" of algae, after the killing

of which by means of copper sulphate, various investigators have noted sudden decreases in the dissolved oxygen content.

TABLE 2. PHYSICAL AND CHEMICAL CONDITIONS OF LAKE JESSE WATER

Date (1934)	Temperature °C. Air	Temperature °C. Surface	Temperature °C. Bottom	pH Value Surface	pH Value Bottom	O_2 c.c. per litre Surface	O_2 c.c. per litre Bottom	Bicarbonate p.p.m. Surface	Bicarbonate p.p.m. Bottom
				STATION 1, DEPTH 4.0 METRES					
July 31	22.8	23.7		6.6		5.93		11.0	
August 1	19.9	22.3	21.4	6.5	6.3	6.04	5.83	10.0	9.9
August 2	23.3	23.5	21.4	6.5	6.3	6.38	5.53	10.1	10.6
August 3	18.9	21.8	21.8						
August 4	22.1	23.2	21.9	6.3	6.3	7.40	6.22	10.7	10.0
				STATION 2, DEPTH 5.5 METRES					
July 31		23.8		6.6		5.97		11.3	
August 1		22.5	21.0	6.5	6.2	6.06	5.62	10.2	10.0
August 2		24.0	21.1	6.5	6.2	6.17	5.66	9.8	9.5
August 4		23.5	21.4	6.3	6.3	6.81	5.66	10.4	9.9
August 7		22.6	20.6	6.4	6.3	5.83	5.08	10.6	9.9

Effect of the Copper Sulphate Upon the Phytoplankton

Copper sulphate has been widely used as an effective algicide, as most algae are very susceptible to low concentrations of this salt. Smith (1924) presents a table showing the effect of various concentrations of copper sulphate upon a number of algae, the table being a compilation of the results of several workers. Practically all of the algae studied were killed by a concentration of .50 p.p.m. of copper sulphate. The effective concentration varied for each species, no doubt depending to a certain extent upon the temperature and chemical conditions of the experimental waters.

It is therefore not surprising that the phytoplankton of lake Jesse was quite thoroughly destroyed. *Hyalotheca* persisted in the plankton samples until October 3. On December 6 none was present. This is a filamentous desmid with a gelatinous sheath. These characters may have been responsible for its continuance in the plankton samples, even if dead. The samples were not examined fresh, but only after preservation in formalin, so we cannot say with certainty whether it was alive or dead, except that many of the cells were empty. The sample of December 6 contained a few cells of *Tabellaria fenestrata,* which appeared to have been recently alive.

The samples of water collected for copper analysis on August 24, September 15, October 3 and December 6 stood for some time in the laboratory before the analyses were made. In the one for September 15, *Aphanothece* (*clathrata?*) flourished, and in the others, a *Palmella*-like species. These samples contained from 1.20 to 2.44 p.p.m. of copper sulphate as $CuSO_4.5H_2O$, concentrations which are usually not compatible with the growth of algae. However, although most species of algae are killed by less than 1 p.p.m. of $CuSO_4$. $5H2_2$ some have been found more resistant. Thus, Kellerman (1912) found that a concentration of 5 to 10 p.p.m. was required to kill *Kirchneriella,* and one of 5 p.p.m. for *Beggiatoa.* Moore and Kellerman (1905) give a concentration of 2 p.p.m. for destroying *Palmella*

sp. Possibly the forms present in our water samples were able to withstand the amount of copper sulphate indicated above. Moore and Kellerman (1905, p. 9) also make the following statement: "The concentration necessary to kill algae in the laboratory is from five to twenty times as great as that necessary to destroy the same species in its natural habitat." In explanation they (p. 9) go on to say "that under normal conditions the rapid growth of the organism is favored, with a subsequent maintenance of the highest degree of sensitiveness to adverse conditions, (but) when algae are brought into the laboratory, the change in environment and the injury from handling allows only the more resistant individuals to persist, and the forms developing from these are, therefore, harder to destroy than those of the same species growing in nature."

It is also possible, perhaps, that the algae were able to grow in the water samples in the laboratory because not all the copper existed as copper sulphate, but in combination with some organic radicle, in which combination, although soluble, its toxicity might be reduced. Silver nitrate is highly toxic to living matter, but argyrol (see above) is comparatively innocuous. Smith (1901) remarks that copper in combination with proteins, as may be encountered in canned vegetables, etc., is but slightly toxic.

A plankton tow secured on December 6, 1934, in lake Jesse contained specimens of the diatom, *Tabellaria fenestrata,* which appeared, although preserved, to have been recently alive. Another sample secured through the ice on March 20, 1935, had the following forms which had apparently been alive when taken: *Asterionella formosa, Tabellaria fenestrata, Tabellaria flocculosa, Fragilaria* sp., *Peridinium* sp. and *Dinobryon* sp. By May 10, a representative each of the genera *Chroococcus, Closterium, Pleurataenium, Staurastrum* and *Micrasterias* were present, and on June 24, *Tabellaria fenestrata, Asterionella formosa* and *Peridinium* sp. were secured in a sample and were undoubtedly alive at the time. In this last sample *Dinobryon, Surirella, Cosmarium* and *Xanthidium* were also present, but it is a question whether they were alive when taken.

Thus, almost a year after the copper sulphate had been added to the lake the phytoplankton still continued to be very poorly represented. For rough comparison, it may be stated that a sample taken on August 2, 1934, a day prior to the treatment, contained at least eighty-eight species of plankton algae.

Effect of the Copper Sulphate Upon the Rooted Submerged and Emergent Vegetation

Caird (1905) observed that potamogetons were destroyed in a reservoir treated with 0.3 p.p.m. of copper sulphate. However, Moore and Kellerman (1905) report that one pound of copper sulphate to one million gallons of water in a park lake had no effect upon water-lilies and cat-tails.

There was no apparent effect of the copper sulphate treatment upon this type of vegetation in lake Jesse during 1934, but the salt was added to the water when the growing period of these plants was past. On May 10, 1935, it was observed that new leaves of the yellow pond lily, *Nymphaea advena,* were showing. The sedges were also putting forth fresh shoots, but the tips of these appeared dead. Pipewort, *Eriocaulon articulare,* was found alive by Mr. James Catt.

Effect of the Copper Sulphate Upon the Zooplankton

As with the phytoplankton, the limnetic zooplankton was completely destroyed, as far as could be determined by fifteen minute hauls with a number five plankton net, although certain species were resistant for some time.

On August 4 the copepods, *Diaptomus minutus* and *Mesocyclops obsoletus,* were still abundant, and *Epischura lacustris* common, in the plankton from the surface and a depth of 3-4 metres. Of the cladocerans, *Holopedium gibberum* was common at both depths, and a few other species were rare at the 3-4 metre level. *Daphnia pulex* which was a fairly common constituent of the plankton before August 3 was entirely absent. The cladocerans were probably represented by weakened, or even dead, individuals, as they were taken, with the exception of *Holopedium,* only near the bottom. The gelatinous sheath surrounding the body of this latter species may have buoyed them up in the water for a greater length of time.

On August 7 no cladocerans were present in the plankton samples. *Mesocyclops obsoletus* was still common, but *Diaptomus minutus* was rare, and *Epischura lacustris* absent. By August 25 the limnetic cladocerans and copepods found in the samples before the treatment had entirely disappeared. The copper sulphate had destroyed that plankton association. The more truly littoral species, *Acantholeberis curvirostris* and *Eucyclops agilis,* were sparingly represented. Watermites were found in the plankton up to this date, although principally nymphs. Later only a few chironomid larvae and *Eucyclops agilis,* with presumably the latter's immature stages, were taken on October 3 and December 6 respectively. On March 20, 1935, a plankton sample showed the presence of the following zooplanktonts: *Anuraea cochlearis, Polyarthra platyptera, Diaptomus minutus, Cyclops viridis,* copepod nauplii and metanauplii, *Daphnia pulex, Bosmina longirostris, Alonella nana* and *Chydorus sphaericus.* Again on May 10, 1935, *Anuraea cochlearis, Diaptomus minutus, Cyclops viridis, Eucyclops agilis, Eucyclops prasinus* and *Mesocyclops obsoletus* were found. Of these latter forms, the copepods *Diaptomus minutus* and *Eucyclops agilis* were most common, *Eucyclops* being represented by females carrying ovisacs. The quantity of plankton on May 10 in comparison with that in the control lake, Hectanooga (May 11), was meagre, as shown by comparative counts from hauls made with a number five plankton net (table 3).

TABLE 3. COMPARATIVE COUNTS OF ZOOPLANKTONTS FROM LAKES JESSE AND HECTANOOGA, MAY, 1935

Forms	Lake Jesse (May 10)	Lake Hectanooga (May 11)
Diaphanosoma	0	2.4
Holopedium	0	21.6
Daphnia	0	144.0
Bosmina	0	7.2
Diaptomus	7.6	337.2
Cyclops	10.6	14.4
Total	18.2	526.8

Effect of Copper Sulphate Upon Other Invertebrate Forms

No sampling was made of the bottom fauna of lake Jesse until May, 1935, except for observations in the littoral zone. As far as could be determined the snails and clams were all killed. The aquatic insect life had a few survivals, to wit, chironomid and *Corethra* larvae. On October 3 an adult caddis fly was secured at the lake. In a number of dredges made on May 11 no live organisms were found in the deeper water, and only a few chironomid larvae in the shallower (1 to 2 metres). A few caddis fly larvae, adult mayflies and caddis flies were observed by Mr. James Catt on May 8 and 19. Sponges were observed alive on the stones, and gyrinids and gerrids were also noted during the May visit.

The leeches, *Herpobdella punctata* and *Macrobdella decora,* were common in the lake. The latter species appeared fairly resistant to the copper sulphate, as apparently healthy individuals were noted on August 9. Moore (1923) found the leeches in Carr pond, Palisades Interstate park, were killed eventually by 0.2 to one p.p.m. of copper sulphate. The above named species occurred in this pond.

Effect of the Copper Sulphate Upon the Fish

The following species of fish were found in lake Jesse:

Salvelinus fontinalis	Brook trout
Notemigonus crysoleucas	Golden shiner
Semotilus atromaculatus	Creek chub
Catostomus commersonnii	Common sucker
Ameiurus nebulosus	Catfish or bullhead
Anguilla rostrata	Eel
Fundulus diaphanes	Killifish
Perca flavescens	Yellow perch
Morone americana	White perch
Pungitius pungitius	Nine-spined stickleback

The killifish, yellow perch and white perch were the most abundant numerically, while the number of brook trout, suckers, creek chub and sticklebacks were small. An estimation of this population, as based upon the number of fish killed, gave approximately 35,000 individuals. For a further account of this fish population see Smith (1935).

Catt (1934) reports that in preliminary experiments, using lake Jesse water, the yellow and white perch were killed in 10 hours by a concentration of 1 p.p.m. of $CuSO_4.5H_2O$. A concentration of 1 p.p.m. has been found sufficient to kill catfish, suckers and trout (Kellerman, 1912), although Marsh and Robinson (1910) determined that this concentration did not kill brook trout fry during forty-eight hours in water with an alkalinity of 53 p.p.m. This discrepancy is not surprisng for the acidity, organic matter content and temperature of the water in which the experiment is being carried out has considerable influence upon the result. It is necessary, as Catt did, to determine the effective concentration in that water which is to be treated, for as Moore and Kellerman (1904, p. 44) say: *"No rule for determining the amount of copper sulphate to be added can be given. Each body of water must be treated in the light of its special condition."*

With this information, and considering the dosage of copper sulphate used, it is to be expected that the fish population of lake Jesse would be annihilated. To a large extent this was true, but an undeterminable number of fish did survive.

On August 5, two days after the copper sulphate had been added, a school of about twenty-five killifish were noted at the outlet from lake Jesse, and two yellow perch and a few eels along the shore. By use of a large seine two small yellow perch were captured on August 6 in a number of hauls at various points about the lake. Catt (1934) also observed killifish on August 9 at the outlet and captured one white perch in a twenty fathom gill-net. On October 3 one killifish was seen. Set-lines (25 hooks), baited with fish and earthworms, captured two ells on May 10, 1935. The same lines continued from May 16 to 21 inclusive yielded no fish. A gill-net set during the entire period of the May investigations caught nothing.

Our observations indicated that a number of eels survived, for on the morning of August 4, there appeared to be a larger number of these fish alive in the shallow water at the immediate shore-line than were later found dead. We anticipated that all would eventually die, so no actual count was made; thus, unfortunately we have no figures to substantiate our observation.

The catfish and eels were the most tenacious of life when affected by the copper sulphate. On August 4, no dead individuals of these two species were observed in the shallow water at the shore, although they were apparently in distress, and the other species of fish were dead in large numbers. However, on August 5 practically all the catfish and eels in the shallow water were dead, with only a few specimens alive, but in poor condition.

It is interesting to note that almost 100 per cent of the dead fish were found in the shallow water within a few feet of the shore, or washed upon the shore. The bottom of the lake could be seen to a depth of four metres, or more, with the aid of a water-glass, and a

search revealed only a very few dead fish on the bottom in the deeper water away from the shore. Likewise only a very few individuals were found afloat. It would appear that once affected by the copper sulphate the fish sought the shallow littoral zone. Eels were found, still alive, out of the water between and on moist rocks. This behaviour probably reflects the manner in which the fish are killed by the copper sulphate. Death is not apparently due to an internal poisoning, but most probably to a precipitation of the mucus on the gills, with a subsequent suffocation. This is the effect in another case of heavy metal poisoning, namely lead, as noted by Carpenter (1927).

From May 9 to 22, 1935, a number of tests were made upon the effect of lake Jesse waters on brook trout fry. The surface water appeared to be innocuous, but the bottom water, particularly when some bottom mud was present, proved fatal to the fish, under the experimental conditions, after forty hours. Although the tests were by no means conclusive, yet the results fit in with the distribution of copper in lake Jesse waters on May 10 (table 1).

Acknowledgment

The author is indebted to the Department of Fisheries for the opportunity of making the observations. The kind aid of Mr. James Catt, District Supervisor of Fish Culture, St. John, N. B., as well as assistance from the staff of the Yarmouth hatchery, is acknowledged. The author is also indebted to Dr. G. S. Whitby for securing the analysis of the water samples for copper. The leeches were specifically identified by Dr. R. J. Myers. This paper is published with permission of the Biological Board of Canada.

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Discussion

Mr. R. W. Eschmeyer (Michigan): The Institute for Fisheries Research of Michigan has been using a substance much more toxic than copper sulphate—so toxic that we prefer not to mention the name. We shall be glad to discuss it with anyone interested. It has a decided advantage over other chemicals in that apparently it does not injure the food or the vegetation, and the lake can be restocked within a very few days.

Mr. Eugene Surber: When we made our first copper sulphate solution, one to two thousand, at Leetown, for the treatment of bacterial gill disease, we found that nearly all of the copper was precipitated out in a very few minutes. This precipitate was a light blue color which I suppose was copper hydroxide but may have been copper carbonate, as Mr. Smith has described. I found that by adding a very small amount of glacial acetic acid to this solution it could be cleared up. I am wondering whether glacial acetic acid cannot be used in large scale treatments such as this for keeping a larger quantity of the copper in solution.

The President: Has anyone had experience with glacial acetic acid?

Mr. Eugene Surber: We have used our copper sulphate with glacial acetic acid many times with success in the treatment of bacterial gill disease.

Mr. Tunison: Do you use that in dipping the fish?

Mr. Eugene Surber: In dipping the fish—a one to two thousand dip.

Mr. Aitken: Referring to the use of copper sulphate under field conditions I would like to cite an experience we had in Iowa in attempting to remove undesirable fish from an area on which we were going to build an artificial lake. The results of that work were published in *Science* for July, 1930, if anyone

would care to look it up. We are at the present time treating a lake in Iowa with copper sulphate; Mr. Rose, under the direction of Dr. Martin of the Botany Department of the State University is in charge of that work. Mr. Rose's report has not been submitted to the Conservation Commission, but I have knowledge of the results that are just about to come out. Throughout the summer, according to Rose, he has used continuously about five parts per million without any deleterious effect on invertebrate life or fish life, and has controlled Aphanizomenon and Microcystis.

Mr. A. S. Hazzard (Michigan): I would like to report the results of the use of copper sulphate in some streams in Utah. The Bureau of Fisheries and the Bureau of Animal Industry carried out a cooperative experiment to determine the effect of the solution commonly used by the Bureau of Animal Industry in controlling snails in streams and ponds in order to control the liverfluke of sheep. This experiment was run for a period of twelve hours. A concentration of two parts per million copper sulphate was used. There was no loss of trout until about eight hours after the end of the period covered by the experiment; in other words, the fish apparently did not assimilate enough copper until the end of that period to affect them. There was then a very heavy loss of trout but practically no loss of food organisms or of algae. The algae were slightly affected but very rapidly recovered. The only organisms affected by that concentrate were the snails which the department wished to eradicate, and also all the trout—a large percentage of the trout in that area were killed where the concentration was two parts per million. The conclusion was quite clear that wherever that concentrate was used in a trout stream the snails would be killed but also all the trout.

ELEVEN YEARS OF CHEMICAL TREATMENT OF THE MADISON LAKES:—ITS EFFECT ON FISH AND FISH FOODS

BERNHARD DOMOGALLA

City of Madison and Wisconsin State Laboratory of Hygiene

Since 1924 numerous public protests to the bad odors and obnoxious water growths existing during the spring, summer, and fall months in the lakes around Madison, Wisconsin, forced the city officials to investigate as well as try to remove the bad lake conditions. Before chemical treatments were begun on Lake Monona the pig-pen like odors were so strong in 1924 that people living along the lake shore had to sleep with closed windows during the summer months. In order to quiet the public protest mass meetings, copper sulphate was dragged up and down the city shores in bags hung over the sides of launches. However, this "hit-and-miss" bag dragging method did not improve conditions; instead many fish were killed where the launches stalled in the dense water weeds and the copper sulphate concentration got too high.

In 1925 intensive studies were made and remedial measures applied to Lake Monona, this being the one whose condition was most noticeable in the city. Studies were made and are still being continued of the bio-chemical fluctuations that take place in these lakes and the factors that influence these changes: stratification, circulation, temperature, light, oxygen supply, agricultural and industrial nature of the water shed, as well as the inflowing drainage and ground waters. Phosphorus, nitrogen, and bicarbonate compounds were found to be important factors causing these obnoxious water growths.

Lakes Mendota, Monona, Waubesa, Kegonsa, and Wingra, forming a chain of glacial hard-water lakes in the Yahara River Valley (Fig. 1) are in drift basins, and are fed from ground waters and some sewage effluents. Their dimensions and other features are given in Table 1. Special notice should be taken of the small lake level drop between Lakes Waubesa and Kegonsa. Both of these lakes are in very bad condition, and are the only lakes left in this chain that are not being treated chemically. Also notice the tremendous size and volume of Lake Monona that has been clear of obnoxious growths and odors for the last eleven years by means of spraying chemicals under scientific control.

COLLECTION AND ANALYSES OF SAMPLES

Laboratory lake equipment modeled after that used by President-Emeritus E. A. Birge and Prof. C. Juday has been used for the studies and scientific control of the chemical treatment of the Madi-

son lakes. Chemical, biological, and bacteriological water samples are collected regularly at various depths from different sections of the chain of lakes. For the biological examinations as well as algae treatment control the method developed by Birge and Juday is followed instead of the Sedgwick-Rafter method. A special high-speed electric centrifuge is used to concentrate the plankton. The net for plankton catch is used to study the zoo-plankton and observe whether the strength of chemicals sprayed is reducing the small animal life in the lake.

Fig. 1—Chain of Lakes at Madison, Wis.

TABLE 1. DATA ON CHAIN OF LAKES AROUND MADISON, WISCONSIN

Lake	Length, Miles	Width, Miles	Area, Sq. Miles	Max. Depth, Ft.	Mean Depth, Ft.	Volume, M.G.	Ave. Drop Between Lakes, In.
Mendota	5.90	4.60	15.20	84.0	39.7	126,385.35	36.0
Monona	4.16	2.40	5.44	74.0	27.6	31,499.95	3.4
Waubesa	4.20	1.40	3.18	36.6	16.1	10,634.58	18.0
Kegonsa	3.00	2.25	4.91	31.4	15.1	15,603.63	----
Wingra	1.00	0.37	----	14.1	8.9	1,479.52	----

Copper Sulphate Spraying Method

Based upon the analysis of the samples taken from the different sections of the lake, copper sulphate treatments are made when found necessary. Experience and studies have shown that it is cheaper to kill the objectionable growths as they start and before the organisms have developed to such an extent as to form a heavy mass giving off bad odors. The old bag dragging method was discontinued and all of the chemicals were administered with power spraying equipment. Each launch with the spraying equipment is operated at a speed that would distribute the required amount of chemical as systematically and as uniformly as possible over a definite prescribed course. The entire surface water of the lake is sprayed on a calm day when the algae count has gone far above normal. About 200 acres of Lake Monona

near the outlet is never sprayed; that being the Wild Life Refuge. Scums in this area move down the outlet and do not disturb the city shores. It was possible to keep the lake free from bad odors and excessive growths for at least one whole month after the entire surface water was sprayed lightly with great care.

At no time were all of the algae in the lake eliminated. However, the greater portion of the lake was clear and in a better condition than the other lakes of this chain. The turbidity or white disk readings averaged around 14 feet for Lake Monona, whereas the disk reading of the other lakes ranged from 2 to 8 feet during the summer months. A great number of counts are made as well as other analyses in order to determine the effect that various treatments had on the condition of the lake water and to make a treatment for certain algae as soon as a marked increase above normal was noticed.

Discussion on Chemical Treatment of Waters

Table 2 shows the effect that copper sulphate had upon the predominating forms of algae. The investigations showed that many of our obnoxious algae can be kept under control with our power spraying methods by using far less chemical than prescribed in Whipple's book on "Microscopy of Drinking Water." By using these smaller spraying doses the zoo-plankton count stayed up all summer and throughout all of the eleven years of chemical treatment as shown in Table 3. Many neutral members of the University of Wisconsin staff, professors and research students, were asked to collect and count these plankton samples. Furthermore, it was also observed that during one chemical treatment the predominant alga form would be greatly reduced in numbers and then some of the minor forms would multiply faster and become the excessive algae growths for the next month.

Chemical treatments are ordered in May each year because of complaints from the city shore residents where algae, like Cladophora Ulothrix cause the trouble. Large masses would come loose from the rocks and other material along the bottom of the shoreline and float on the surface. In a short time these masses would decay and give off bad odors. Generally in June, Anabena becomes a nuisance. It is so sensitive to our spraying methods that it never appears again on Lake Monona for that particular season, although it is found all summer in the neighboring lakes, where strong complaints about algae scums and odors have been sent to the Governor of the State. During July and August, the offensive Microcystis followed by Hydrodictyon and Aphanizomenon appear on the surface waters in great numbers. The September water growths vary considerably from year to year depending upon the weather conditions. Generally Aphanizomenon, Cladophera, and Ulothrix are the ones that cause

complaints. The zoo-plankton count, especially the crustacea and rotifera vary much from season to season. This count is much higher during a cool rainy summer than during a hot summer, even though the algae count is high during some hot seasons.

TABLE 2. LAKE MONONA PLANKTON COUNTS. COPPER SULPHATE SPRAYING METHOD. JUNE-JULY, 1935

Composite samples over surface of lake.	No. of organisms per liter of water. —Time after June 3rd treatment—				
	Just before Treatment 6/3/35	3 days after	9 days after	20 days after	July first just before next treatment
Anabena	220,000.	88,500.	55,400.	29,800.	49,900.
Microcystis	150,500.	74,600.	46,800.	*42,600.*	*202,300.*
Fragilaria	74,100.	39,000.	29,800.	11,300.	26,800.
Pediastrum	51,500.	30,200.	19,900.	14,200.	21,900.
Synedra	45,600.	25,300.	17,000.	18,500.	*58,600.*
Hydrodictyon	40,200.	19,800.	12,700.	*22,700.*	*47,100.*
Aphanizomenon	38,400.	18,000.	9,900.	11,300.	39,850.
Rivularia	29,600.	15,500.	8,500.	7,100.	8,900.
Ceratium	20,800.	7,300.	1,600.	2,200.	3,400.
Scenedesmus	16,900.	5,500.	2,800.	5,600.	6,800.
Total Number*	735,600.	353,900.	216,500.	165,300.	475,500.

*Total number includes the other minor algae, protozoa, etc.

Total copper sulphate treatment for June 3-4, 1935, was:—17,550. pounds
Total volume of Lake Monona in 1935 is:—31,490,000,000. gallons

$$\frac{17{,}550}{31{,}490} = 0.50 \textit{ pound of copper sulphate per million gallons of water}$$

July 1-3 copper sulphate treatment required:—28,300. pounds.

$$\frac{28{,}300}{31{,}490} = 0.90 \textit{ pound of copper sulphate per million gallons of water}$$

TABLE 3. COMPARATIVE PLANKTON COUNTS ON LAKES AROUND MADISON, WISCONSIN
(During eleven years of chemical treatment of Lake Monona)

Average during summer months (June, July, August).			No. of organisms per liter of water	
Name of Lake	Green and Blue-green Algae, Diatoms and Protozoa.*		Crustacea and Rotifera**	
	1925	1935	1925	1935
Mendota	425,000.	376,000.	85.	71.
Monona	710,500.	324,000.	125.	102.
Wingra	1,950,000.	985,000.	118.	66.
Waubesa	2,100,000.	1,676,000.	65.	54.
Kegonsa	950,000.	1,150,000.	69.	41.

*Count made on centrifuged material, taken in the middle of the lake.
**Count made on net haul material taken in the middle of the lake.

That the copper sulphate spraying of the lakes about Madison helps keep saprolegnia under control was definitely proven in 1930. During May and June of that year thousands of diseased fish, chiefly perch and bluegills floated about Lake Mendota and were finally washed to shore. This epidemic also affected some of the fish in Lake Monona. That these fish dying at that time were seriously infected with saprolegnia was verified by the University biologists. The latter part of May, 1930, when the regular copper sulphate spraying was begun in Lake Monona the saprolegnia infection took a decided drop. However, in Lake Mendota the diseased fish floated on the lake all through the month of June and part of July. The

city had to keep a staff of ten men constantly checking over the Lake Mendota shoreline all through July, picking up diseased dead fish.

Weed and Bathing Beach Treatments

A careful biological survey made in 1925 showed that of the 5.4 square miles of surface area of Lake Monona, about 600 acres were infested with rooted weeds where the algae scum would accumulate and produce a so-called "water-bloom." Complaints made by the public demanded that the obnoxious water weeds be removed. By means of a weed cutting machine, or steel cables with clips attached, or chemicals, the rooted water weeds were removed from the numerous bathing beaches and in front of boat houses. However, the recent 1935 survey made by a special committee showed that there are still 400 acres of rooted water weeds left. Most of these are left undisturbed in the section set aside as a "Wild Life Refuge" area. For the last eleven years the weeds have grown luxuriantly in ten to eighteen foot depths of water off the city shore. This finding pleases the fishermen, who first thought the chemical treatments through these years would kill every weed in the lake.

After the excessive algae and rooted weed growths were kept under control around the bathing beaches the public demanded still more treatments in order to protect the swimmers from bacteriological and fungous infections. Chlorine treatments were made around the beaches for a time but were soon discontinued since the fish were found to be far more sensitive to chlorine than to copper sulphate. The studies on the effect of chlorine treatments on fish life will be reported in a separate paper.

Conclusions

Eleven years of scientific study and chemical treatment of the lakes about Madison, Wisconsin, especially Lake Monona, have brought out important points to be considered in improving various bodies of water:

1. The spraying method of copper sulphate and other chemicals is most effective and economical in keeping obnoxious algae under control.

2. Eleven seasons of spraying chemicals on the waters of Lake Monona was carried out to prevent algae scum formation but not to kill off the zoo-plankton.

3. The spraying method applied to keep the algae under control also kept the fish fungous under control.

4. The rooted water weeds grew luxuriantly through all of these years of copper sulphate treatment.

5. Weed cutting machines, steel cables, and arsenical compounds had to be used to remove the rooted water weeds around the beaches and boat-houses.

6. The years of chemical and bacteriological and biological studies on the chain of lakes showed that the different forms of nitrogen, phosphorus, and bicarbonate compounds are the chief growth promoting factors that cause the excessive algae scum and weed growths; some of these growth promoting factors are produced right in the lake itself, as well as in the inflowing waters.

ACKNOWLEDGMENTS

The years of intensive laboratory studies are still being carried out by the writer in the Wisconsin State Laboratory of Hygiene, University of Wisconsin. The large scale treatment work requiring annually about $7,000 worth of chemicals and $15,000 worth of treatment equipment is directed by the writer under the supervision of the Rivers and Lakes Commission of the City of Madison. All of the members on this Commission, especially Dr. F. F. Bowman, the health officer, rendered valuable service in meeting the numerous complaints and troubles that come about in carrying out such large scale treatment projects. Dr. W. D. Stovall and Dr. M. S. Nichols, as representatives of the State Laboratory of Hygiene, were ordered by the State Board of Health and other committees to make unbiased investigations as well as render valuable suggestions from time to time.

DISCUSSION

MR. CULLER (Wisconsin): I would like to ask whether the fishing has been better in Lake Mendota and the other lakes since the treatment of copper sulphate was used?

MR. DOMOGALLA: Opinions of the fishermen on that subject vary a good deal. Some of the fishermen say they do not get a bite; others say they get a lot of bites. We plan to make a survey and study of our own on a scientific basis.

MR. CULLER: At a recent conference held at Madison between the sportsmen and the city officials it was suggested that one of the reasons for the lack of fishing was the pollution that has been dumped into Lake Mendota and other lakes from the hospitals around the shore.

MR. DOMOGALLA: That is all being discontinued; we are forming now a sanitary sewage district which is being hooked up into the metropolitan sewage plant.

MR. CULLER: Do the sportsmen around Madison not claim that fishing has gone back in the lakes?

MR. DOMOGALLA: There are varying opinions—it comes in schools. Sometimes you get some fish; sometimes you do not get any. It varies.

MR. CULLER: At the conference to which I have referred they were bringing that matter to our attention. I was wondering whether copper sulphate was responsible for the lack of fishing, or the effects of copper sulphate, or whether it was due to the pollution or some other cause.

MR. DOMOGALLA: They blame it on the pollution, because you can see the algae count has gone up, and also the zoo plankton is up. But the sewage is being hooked up now with the metropolitan district—

MR. CULLER: It is not hooked up yet, is it?

MR. DOMOGALLA: No.

THE PRESIDENT: Was there any mortality among any species of fish after treating the lake?

MR. DOMOGALLA: No, we had no mortality.

DR. HUBBS: What was the source of the skin infections to which some people were subjected who were using the bathing beaches?

MR. DOMOGALLA: Those were human fungus infections—we do not know just where they came from. We found that all over our bathing beaches people were breaking out in various skin rashes. The greatest amount of skin infection was found at Lake Mendota. Only two complaints came to the city board of health with regard to skin infections on Lake Monona, where there were two hundred and fifty from Lake Mendota. These were cases that actually came in for treatment.

MR. CULLER: Would you attribute the skin disease to the fact that the hospitals were dumping their sewage into the lake?

MR. DOMOGALLA: That is on the other side of the lake. It runs out across the current; I do not think it comes to the other side. The greatest infection was at University Bay, which is at the extreme opposite end.

MR. CULLER: Isn't it possible that the bacteria from the hospitals could spread over the lake and cause these diseases?

MR. DOMOGALLA: The characteristic sign of pollution would be the presence of B. coli, and we did not get a trace of B. coli showing signs of pollution.

MR. CULLER: B. coli is one sign of pollution, but couldn't the skin diseases be attributable to the hospitals dumping their sewage into the lakes?

MR. DOMOGALLA: We do not find as much on that side. We made the fungus counts across the lake, and it seems to increase in spots. University Bay is full of decaying debris and that in itself could cause a lot of fungus infection.

MR. CULLER: Do you think the diseases from vegetable matter would be coincident with the diseases in the human being?

MR. DOMOGALLA: No, but that would be the basis of the food supply. When such large crowds are swimming there, including some who have the infection, and the water temperature goes up to 85 or 90 degrees, it will spread very rapidly. It holds true even more so on Lake Michigan; they have the same condition in the city of Milwaukee.

MR. CULLER: You could hardly compare Lake Michigan with Lake Mendota, on account of the size.

MR. DOMOGALLA: From the standpoint of pollution, certainly. The pollution factor in your sewage would be considerable, and you have a big fungus growth there.

MR. CULLER: Has there been study on that particular point?

MR. DOMOGALLA: I made one which will be published later.

A PRELIMINARY STUDY OF AN EXCEPTIONALLY PRODUCTIVE TROUT WATER, FISH LAKE, UTAH*

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Introduction

A definite need exists for detailed studies of different classes of trout waters which have established ratings by fishermen as poor, average or exceptionally productive. A creel census, such as will be described by Mr. Eschmeyer (1935) during these meetings, would serve to definitely classify such waters and would indicate the actual range of their productivity. The results of limnological studies of a number of each class would then furnish reliable yardsticks for the evaluation of other waters and possibly indicate how the less productive might be improved.

Experience of fishermen in the Intermountain Region has clearly demonstrated the exceptionally productive character of Fish Lake, Utah. This lake is visited annually by many thousands of anglers from Utah and all the neighboring states. A thirteen day check of the catches made during the first of the season of 1934 by the Utah Fish and Game Department showed that 17,521 trout having a total weight of 13,844 pounds were caught during this period. In taking these fish $27,246.21 were spent for travel, meals and supplies; a cost of about two dollars per pound of trout. If the period checked may be considered representative of the fishing during the entire season of approximately ninety days, the total yield for this lake would be 95,850 pounds having a cash value to local businesses of $191,700. On this basis, a yield of 38.3 pounds per acre is indicated. While the present study is preliminary, it is believed that some of the factors responsible for this phenomenal production are definitely indicated. The study was made from July 21 to 31, 1933, in cooperation with the Utah Fish and Game Department.

After sounding the lake, eleven stations were selected at various depths and over different types of bottom at which samples were collected.

Summary of Findings

General description of the lake.—Fish Lake is at an elevation of 8,800 feet and is situated in a region of past volcanic and glacial activity. It is five and one-fourth miles in length by an average of three-fourths mile wide; the area being roughly 2,500 acres. The long axis of the lake extends in a northeast-southwest direction. The

*Investigation made while employed by U. S. Bureau of Fisheries. Published with permission of the Commissioner of Fisheries.

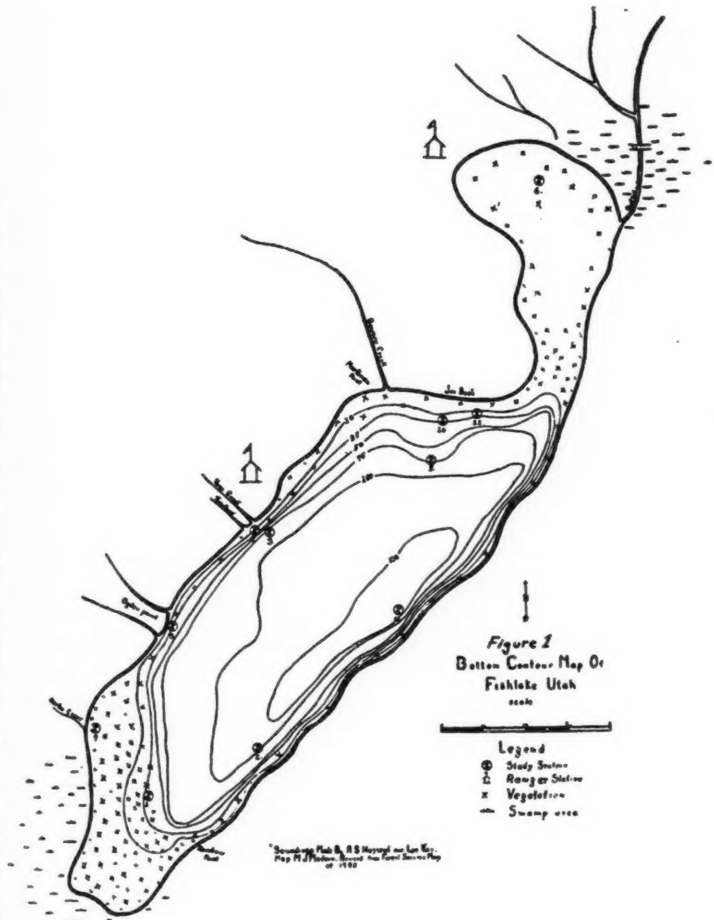

Figure 1
Bottom Contour Map Of
Fishlake Utah

precipitous, wooded, rocky shore of the southeast side is in direct contrast to the more gently sloping hills of the northwest and the marshy flats at each end.

The lake is supplied by six spring-fed streams, only one of which is of sufficient size to furnish any spawning area for trout from the lake, and in this one the area is restricted to less than one-half mile. The excellent fishing maintained in this lake is believed to be almost solely due to consistently heavy plantings by the State Department.

Physical data.—A bottom contour map (Figure 1) prepared from 140 soundings shows that about seventy per cent of the lake is over ninety feet in depth; the maximum being 117 feet. The principal shoals and weed beds are at the ends and along the northwest side.

Surface water temperatures varied from 64 to 69° F. during the period of the survey. A definite thermocline was found at from twenty-five to sixty feet below which the temperature decreased to 40° F.

The water is white in color and quite clear. A six inch white disk disappeared from sight at depths ranging from forty-one to forty-five feet.

Beyond the thirty foot contour, the lake bottom is largely of mud mixed with a varying quantity of decaying water plants. The shoals are largely of gravel, peat and mud and are more or less densely covered with vegetation.

TABLE 1. DISTRIBUTION AND ABUNDANCE OF PLANTS IN FISH LAKE
(Identifications by Dr. Walter P. Cottam, University of Utah)

Species	Location	Depth in feet	Abundance
Elodea planctonii	north and south ends of lake	5-10 feet	very abundant
Zannichellia palustris	north and south ends of lake	5-10 feet	very abundant
Potamogeton praelongus	around border of lake	8-25 feet	common
Myriophyllum spicatum	around border of lake	8-25 feet	common
Ceratophyllum demersum	around border of lake	8-25 feet	common
Lemna trisulca	north and south ends of lake	surface	common
Chara sp.	in majority of lake	10-75 feet	common
Nostoc, sp.	most abundant along shores	0-60 feet	abundant

Chemical data.—Dissolved oxygen, during the period July 21 to 31, was found to be adequate, ranging from 6.5 to 10.7 parts per million, except in water greater than 100 feet in depth where 2.2 parts per million were found at a depth of 103 and 0.9 parts at 113 feet. Carbon dioxide varied from zero at the surface to 17.5 parts per million at a depth of 113 feet. The pH was acid (6.4) in the deeper waters and alkaline (7.4 to 8.5) in water less than 100 feet in depth. Methyl orange alkalinity varied from 50 to 63.5 parts per million and phenolpthalein alkalinity was found only at the surface at one station and in the outlet waters. On the basis of bicarbonate content, Fish

Lake would be considered as intermediate between the hard and soft water classes proposed by Ricker (1932). The known productiveness of Fish Lake indicates that hard water may not be essential to a heavy yield of crustacean fish food and trout.

Biological data.—The great abundance of aquatic plants in Fish Lake "together with other favorable conditions" (not discussed by them) have been suggested by Hildebrand and Towers (1927) as being responsible for the high production of trout. Our study tends to verify this conclusion and to explain these "other favorable conditions." The description of the plant beds in Fish Lake, which these writers quote from a report by S. B. Locke, is excellent. However, several additional plant records are given in our Table 1. The distribution and relative abundance of plants are shown in Table 1 and in Figure 1. The type of bottom, richness of soil and presence of protected shoal areas are doubtless responsible for the quantity of plants produced in Fish Lake.

The fish food supply (Table 3) was studied as intensively as time and our equipment would permit. The most important food item is the freshwater "shrimp" or scud (*Gammarus limnaeus*) which were found under every rock along the shore. As many as twenty-five were counted on a stone approximately six inches in diameter. From imperfect Ekman dredge samples, the number of these crustaceans in the dense weed beds was estimated at from 200 to 500 per square foot of bottom surface. A few scuds were taken as deep as seventy-seven feet. Other shore foods were also present in quantity. Snails, midges, leeches, mayflies, caddisflies and damselflies were seen in almost every collection of weeds examined.

Plankton organisms were very abundant at the time this study was made as evidenced by vertical hauls at six stations using a number

TABLE 2. BOTTOM AND PLANKTON FOOD OF FISH LAKE, UTAH—JULY, 1933

Station No.	Depth in feet	Bottom Type	Crustacea (*Gammarus*)	Mollusca	Oligochaeta	Diptera	Hirudinea	Ephemerida	Hydracarina	Odonata	Total volume of bottom food	Plankton haul in feet	Vol. of plankton—cc.
1	31	Mud, gravel, vegetation	42	11	4	7	2	—	—	—	1.40	26	1.4
2	109	Silt, detritus	—	—	22	—	—	—	—	—	.60	98	4.4
3	77	Silt, sand, gravel, plant fragments	3	2	9	—	2	—	—	—	1.00	64	2.3
4	123	Silt, detritus	—	1	35	—	—	—	—	—	.40	109	6.5
5	76	Clay, detritus	—	1	23	—	—	—	—	—	.45	65	6.6
7	10	Gravel, silt, vegetation	61	—	—	7	7	1	7	—	.75	No sample	
8	30	Silt, gravel, vegetation	33	7	3	—	5	—	—	—	.70	No sample	
10	27	Clay	6	—	—	—	—	—	—	—	.20	No sample	
11	25	Silt	31	—	—	3	4	—	1	1	.40	No sample	

twenty silk net having an opening of thirty centimeters. From 1.4 to 6.6 cubic centimeters (24 hours precipitation) of plankton were obtained.

Deep water bottom organisms were relatively few, ranging from 0.2 to 1.4 cubic centimeters per Ekman (water displacement method).

The native cutthroat trout, *Salmo pleuriticus,* has been virtually displaced by plantings of rainbow, mackinaw and eastern brook trout. About twenty cutthroat were reported to have entered the fish traps at the spawning station during the spring of 1933. Stocking records from January, 1930, to July 13, 1935, furnished by the Utah Fish and Game Department, show a total planting of 2,043,088 rainbow trout (small fingerlings to fourteen inch fish), 3,887,180 brook trout (fingerlings and eyed eggs) and 305,000 fingerling silver and chinook salmon.

Mackinaw trout, *Cristovomer namaycush,* were introduced about twenty years ago and have maintained themselves entirely by natural reproduction. They form a considerable part of the catch, being taken up to thirty-five pounds in weight. Considering the great area of deep water which would not be fully utilized by other species, the introduction of mackinaw is thought to have been justified although stomach examinations of three large individuals taken in November indicate this species may feed extensively on eastern brook trout. These fish weighing from nine to 13 pounds had eaten from one to three brook trout from five to ten inches in length.

Rainbow trout appeared to be the most abundant species of game fish at the time our study was made; 11.3 fish were taken per hour by the Bureau's 125 foot graded size gill net in three one hour sets. The rainbow attains a weight of nine pounds in Fish Lake though the average fish is probably about two pounds.

Twenty specimens from 7.6-19.6 inches (total length) had an average condition factor $a = \frac{100\,W}{L^3}$ of 1.414. Rate of growth, as calculated from scale measurements of 25 fish, was as follows: at first annulus length of fish was 2.9 inches, at second 7.5, at third 12.4, at fourth 15.4, at fifth 17.6 inches. Stomach examinations of 39 rainbow

TABLE 3. SUMMARY OF STOMACH EXAMINATIONS OF 39 RAINBOW FROM 7.6-19.6 INCHES TAKEN DURING THE SURVEY

Food Organisms	Percentage of trout containing this food	Percentage of total volume of food eaten by all trout
Ephermerida: Mayfly nymphs	5.1	.1
Diptera:		
Midge larvae	35.6	.2
Midge pupae	15.3	.6
Coleoptera: Beetle larvae	2.5	.5
Hemiptera: Bugs	2.5	.1
Hydracarina: Water Mites	7.6	.2
Homoptera: Plant lice, etc.	5.1	3.6
Hirudinea: Leeches	2.5	.1
Odonata: Damselflies	7.7	.2
Mollusca: Clams, snails	20.5	18.8
Microcrustacea: Cladocerans	43.5	8.9
Malacostraca: Shrimp	100.0	33.7
Algae: Nostoc, etc.	23.0	13.2
Vegetation: Higher plants	41.0	19.8

(table 3) showed that shrimp made up 33.8 per cent of the total volume of food eaten; being found in every stomach examined in numbers from 3 to 461. Water plants, including algae, made up 33 per cent of the volume. The fact that nearly 20 per cent of these plants were higher aquatics such as pondweeds and *Elodea* is worthy of note. Mollusks, largely snails, were third in importance followed by plankton (Cladocerans).

The initial plantings of brook trout in Fish Lake commonly grew to a weight of five pounds, but of late years the average size has steadily decreased until at present a two pound fish is rare. Intensive angling and the increase in abundance of the rainbow are probably responsible factors. Three gill net sets of one hour each yielded an average of 2.3 brook trout per hour.

The brook trout shows a slightly higher condition factor than that of the rainbow probably because a number of recently spent rainbow were included in the calculations. Fourteen brook trout had an average value for *a* of 1.446. The growth rate of this species is considered satisfactory though not as rapid as that of the rainbow. Scale measurements of fifteen specimens from 7.7 to 13.9 inches indicated: a length of 4.6 inches at the first annulus, 8.3 at the second, 10.6 at the third and 12.9 at the fourth. The food of seventeen brook trout (table 4) indicated that at this season plankton (Cladocerans) were of first importance being found in 64.5 per cent of the stomachs and making up 44.8 per cent of the total volume of food eaten. Shrimp were second followed by dipterous larvae, pupae and adults. Mollusks were of minor importance in contrast to their significance in the diet of the rainbow.

TABLE 4. SUMMARY OF STOMACH EXAMINATIONS OF SEVENTEEN EASTERN BROOK TROUT 7.7 TO 13.9 INCHES TAKEN DURING THE SURVEY

Food Organisms	Percentage of trout containing this food	Percentage of total volume of food eaten by all trout
Ephermerida: Mayfly nymphs	41.0	.4
Plecoptera: Stonefly nymphs	5.8	.6
Diptera: Two-winged flies, midge larvae	41.0	8.1
Homoptera: Plant lice, etc.	17.6	3.2
Odonata: Dragonflies, damselflies	5.8	4.9
Hirudinea: Leeches	5.8	1.3
Hydracarina: Water mites	5.8	.6
Oligochaeta: Worms	5.8	2.1
Microcrustacea: Cladocerans	64.5	44.8
Malacostraca: Shrimp	52.8	31.3
Algae: Nostoc, etc.	11.7	2.1
Vegetation: Higher plants	----	----
Mollusca: Clams, Snails	5.8	.6

Bullheads (*Cottus* sp.) are native to the lake but are not abundant. Chubs (*Tigoma atraria*) and shiners (*Cheonda hydrophlox*) have been introduced by fishermen using them as bait. This illustrates the danger of the unrestricted use of live bait since the chub has become so numerous as to be a distinct annoyance to fly fishermen. The net sets made yielded nineteen chubs per hour, indicating their great abundance as compared with the trout. Scale calculations of twenty-six

specimens from 4.2 to 7.9 inches total length showed the following growth: 1.3 inches at the first annulus, 3.5 at the second, 5.5 at the third, 6.6 at the fourth and 7.4 at the fifth. This slow growth is undoubtedly attributable to the cold water of Fish Lake and to the short growing season afforded such a warm water species. Stomach examinations have shown them to be competing directly with trout, and since there is no evidence that trout consume them, this competition appears to be without compensation. Further study to determine the full extent of the competition and the means for control of the chub is in progress.

Conclusion

More intensive studies of such waters as Fish Lake coupled with accurate catch and planting records would be of great value in determining the proper management of trout lakes in this country.

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Discussion

Mr. Markus: I would like to know what bait they used in the lake to catch the rainbow trout.

Dr. Hazzard: It is really an astonishing piece of apparatus. It extends about from where my hand is to the floor (indicating about seven feet). It has a single wire leader and along this leader there are a series of large plates, either of copper or of brass or of nickle. Then at the tail end you have just a single hook which is baited with worm or minnow.

The President: What is the first organism fed upon after the yolk sac is absorbed in this particular lake?

Dr. Hazzard: I presume it would be crustaceans. Daphnia are very abundant. They could find plenty of food there.

Dr. Hubbs: Dr. Hazzard has given us a very interesting yardstick by which to mesaure other lakes. I suggest the possibility of such studies indicating how other lakes might be improved.

FOOD OF TROUT FROM LAKES IN THE KLAMATH RIVER WATERSHED

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The stomach contents of ninety-five trout taken with hook and line from thirty-two small mountain lakes in the Klamath River watershed (Northern California) were examined. The specimens were collected by the writer while working with a survey party of the U. S. Bureau of Fisheries during the summer of 1934. Grateful acknowledgment is here made to Dr. P. R. Needham and Mr. A. C. Taft of the Bureau of Fisheries, whose kind cooperation greatly facilitated the collection and working up of the material.

The numbers of trout of different species and sizes and the months and localities in which they were taken are given in Table 1. Only one to five specimens were taken from any one lake.

Method of Analysis: The contents of stomachs only were examined. All the heads of food organisms found in each stomach were counted and classified as shown in Table 2. In a few cases, where large numbers of similar, small organisms were found, the contents of the stomach were spread evenly in a small pan, the bottom of which was divided by lines into squares. The heads of organisms in 12 per cent to 20 per cent of the squares were counted and the total number in the stomach arrived at from these figures. (Actual counts made to check the accuracy of this method proved it quite satisfactory.) All, or at least large samples, of the entire (unfragmented) organisms of each type from all the stomachs were preserved in 4 per cent formalin and weighed to obtain the mean wet weight. From these figures and the total counts the approximate total weight of all the organisms of each type was calculated. Before weighing, the organisms were placed in a fine-meshed copper or silk strainer, which was then pressed and tapped on blotting paper for two minutes to remove external moisture. In cases where different stages of life history or species differing greatly in size are included in the same group, these were generally counted and weighed separately to obtain more accurate total figures.

The nature of our sample is such that we are not in a position to make a significant comparison of the foods eaten in the different months, in the different individual lakes, or by different species of trout. The sample is quite adequate, however, to be used as a basis for comparison of the relative importance of the various food organisms found in these lakes in general during the summer months.

Since, with a few minor exceptions, the lakes are very similar in character, such a comparison is quite significant.

In Table 2 are listed for each group of organisms: the total number of the organisms found in the ninety-five stomachs, the number of stomachs in which they occurred, the total wet weight, and the percentage by weight of all the food that contributed. The table is self-explanatory, but a few pertinent remarks may be added. The numbers of these refer to corresponding numbers under "remarks" in Table 2.

(1) 65 per cent by weight of all the food consisted of aquatic organisms, the remaining 35 per cent being terrestrial. Approximately 79 per cent consisted of aquatic forms and the terrestrial adults of forms having aquatic larvae or naiads. Many of the latter were eaten just after they had emerged and before they had left the water.

(2) The importance of Odonata naiads is unusual, and we must remark that of these 75 per cent by weight were eaten by two large rainbow trout (sixteen inches long). They are apparently important as food of large trout only.

(3) Chironomid (midge) larvae and pupae contributed 41.8 per cent by number of the organisms found, and occurred in 80 per cent of the stomachs examined. They were found in twenty out of twenty-two Ekman dredge bottom samples taken at the same time as the stomachs in the lakes under consideration, and constituted 61.4 per cent by number of the food organisms taken in these samples.

(4) The Entomostraca were mostly Cladocera. Also Copepoda and Ostracoda.

(5) Gastropoda were represented by snails, clams, and limpets. The small number of clams (nine in all) found in the stomachs is of interest, because they were found to be plentiful in the bottom silt (contributing 17.4 per cent by number of the food organisms taken in the twenty-two Ekman dredge samples), and because we know that they constitute an important part of the food of trout in other localities, e.g., the lakes of the high Sierras. The reason may be that our lakes are sufficiently rich in other foods, so that the fish are not forced to seek out these less easily available organisms. Another interesting fact is the complete absence in the stomachs of small annelids, which were also very abundant in Ekman dredge samples from the silt bottoms of many of the lakes. They are probably not available to trout and should not be considered as food organisms.

(6) The "Miscellaneous aquatic" group includes: 1,228 Corethra larvae (Culcidae), one Alder-fly larva (Neuroptera), one Asellus (Isopoda), 187 adult water-mites (Arachnida), and 957 minute larval mites.

(7) The bulk of the Homoptera were aphids.

(8) The "Miscellaneous terrestrial" group includes: eight adult

snake-flies (Neuroptera), twenty-nine terrestrial Arachnida, one larval and one adult moth (Lepidoptera), one adult stone-fly (Plecoptera), and ninety-nine Thysanoptera.

TABLE 1. TROUT FROM LAKES OF THE KLAMATH RIVER WATERSHED USED FOR STOMACH EXAMINATION. 1934.

A—DISTRIBUTION OF THE SPECIMENS BY SPECIES AND LENGTHS

(Measurements from tip of snout to fork of tail)

Length in inches:	5-7	7-9	9-11	11-13	13-16	16-22	Total
Rainbow Trout	3	9	14	8	4	4	42
Brown Trout	0	2	4	5	2	0	13
Eastern Brook Trout	13	12	7	7	1	0	40
Total	16	23	25	20	7	4	95

B—DATES AND LOCALITIES IN WHICH SPECIMENS WERE TAKEN

Date	Number of trout	Lakes	Number of lakes	Elevation in feet
June 19-26	29	Lakes at headwaters of Scott & Trinity Rivers	7	5800-7100
July 9-22	56	Lakes in the Marble Mountains	21	5500-7300
August 10-12	6	Fish & Blue Lakes (Bluff Cr. drainage)	2	1700-3000
September 5	4	Meeks & Taylor Lakes (Scott R.-Salmon R. divide)	2	6300-6600
Total	95		32	

TABLE 2. FOODS FOUND IN STOMACHS OF 95 TROUT FROM LAKES OF THE KLAMATH RIVER WATERSHED. 1934.

Organisms*	Number	Times occurring	Wet weight in grams	Per cent by weight	Remarks**
Aquatic:					(1)
Odonata N.	120	19	20.027	24.4	(2)
Chironomidae L. & P.	15,263	77	11.483	14.0	(3)
Trichoptera L. & P.	523	39	7.192	8.7	
Aqu. Hemiptera	36	7	3.554	4.3	
Ephemerida N.	230	34	2.974	3.6	
Amphibia (Tadpoles)	2	1	2.905	3.5	
Amphipoda	756	15	2.035	2.5	
Entomostraca	9,619	37	1.040	1.3	(4)
Aqu. Coleoptera L. & A.	56	19	0.846	1.0	
Aqu. Plants	———	8	0.685	0.8	
Gastropoda	64	10	0.350	0.4	(5)
Miscellaneous Aqu.	2,374	28	0.358	0.4	(6)
Terrestrial:					(1)
Homoptera	5,135	31	4.917	6.0	(7)
Ter. Coleoptera A.	410	34	4.792	5.8	
Odonata A.	26	7	4.540	5.5	
Ephemerida A.	286	26	4.473	5.4	
Hymenoptera A.	422	36	3.325	4.0	
Diptera A.	744	41	2.679	3.3	
Trichoptera A.	150	22	1.514	1.8	
Orthoptera	9	5	1.200	1.5	
Ter. Hemiptera	129	24	0.715	0.9	
Miscellaneous Ter.	139	26	0.665	0.8	(8)
Totals	36,493		82.233		

*Explanation of abbreviations: A.—Adults; L.—Larvae; P.—Pupae; N.—Naiads (Nymphs); Aqu.—Aquatic; Ter.—Terrestrial.

**For remarks see text.

SOME RESULTS OF FORAGE FISH INVESTIGATIONS IN MICHIGAN

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Some of the results of the forage fish investigations, conducted by the writer during the past two years for the Institute for Fisheries Research of the Michigan Department of Conservation, constitute the subject matter of this paper. The investigations have included: (1) the experimental propagation of certain forage species in ponds, (2) observations on the life histories of certain species in natural waters and in hatchery and other rearing ponds, and (3) experiments at the Institute Laboratory in the Museum of Zoology of the University of Michigan.

PROPAGATION EXPERIMENTS

During 1934 the writer cooperated with the late Henry A. Schuil in conducting certain propagation experiments on six species of forage fishes at "Schuil Acres," an experimental rearing station which he had constructed at Grand Rapids, and which at this time was operated under the Department of Conservation. During 1935 the following experiments were conducted: the propagation of the western golden shiner (*Notemigonus crysoleucas auratus*) and the chub sucker (*Erimyzon sucetta kennerlii*) in two trout-rearing ponds, owned by U. Sidney Beach, at Highland, Oakland County, Michigan; propagation of the northern red-bellied dace (*Chrosomus eos*) in a single pond at the Drayton Plains state fish hatchery; and propagation of the blunt-nosed-minnow (*Hyborhynchus notatus*) and the northern fat-head minnow (*Pimephales promelas promelas*) in a single pond at Utica, Macomb County, Michigan. Although complete results are not yet available on all of the 1935 experiments, sufficient information has been obtained to justify mentioning these experiments.

"SCHUIL ACRES," 1934

The Schuil station consisted of a series of 5 artificial ponds, situated along the banks of a small stream. During the early spring the empty pond basins were fertilized, with a total of 7,200 pounds of cow manure and 300 pounds of sheep manure (total cost, $26.70). The water supply for the ponds consisted of seepage from the adjacent stream and from underground springs. The different amount of spring seepage into the ponds was reflected in the wide difference in water temperatures of the ponds during the summer (Table 1).

Various physical data on the ponds, taken during the course of the experiments, are summarized in Table 1 and Figure 1. All ponds

TABLE 1. DATA ON THE MINNOW PROPAGATION EXPERIMENTS AT "SCHUIL ACRES" DURING 1934

Species	—Brood stock—		Young produced per acre		Data on ponds								
							Ave. daily (2 P. M.) water temp. in degrees F.						
	Number	Total length, inches	No.	Weight, lbs.	Pond No.	Area, acres	May (23-31)	June	July	Aug.	Sept. (1-23)	May 23 to Sept. 23
Hyborhynchus notatus	750	2 to 3.5	104,800	250	6	.19	72	78	79	73	67	74
Fundulus diaphanus menona	346[1]	2 to 3	79,900	78	5	.18	70	74	75	71	67	71
Chrosomus eos	2,700	1.3 to 2.2	128,000	240	7	.16	73	78	79	75	69	75
Notemigonus crysoleucas auratus	84	4.5 to 7	42,900	60	3	.15	63	67	68	67	62	65
Notropis cornutus chrysocephalus	145	3.5 to 7	———	—	4	.15	58	59	59	59	56	58
Nocomis biguttatus	85	4 to 7	———	—								

[1] Seventy-one per cent females.

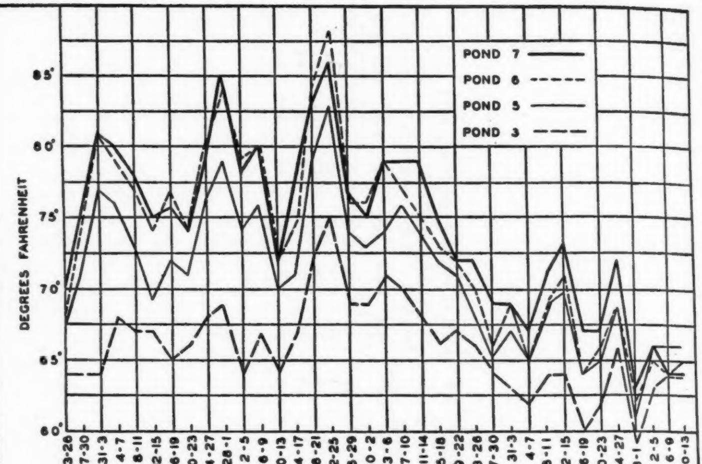

Fig. 1—Graphs showing average water temperatures in ponds at "Schuil Acres" during 1934. Each temperature plotted above is an average of 4 consecutive readings taken daily at 2 P.M. Detailed data not given in this paper.

maintained an abundant growth of *Chara,* and ponds 5, 6 and 7 also supported a considerable growth of filamentous algae.

Six species were used for the propagation experiments in the five ponds, namely: the blunt-nosed minnow (*Hyborhynchus notatus*) in pond 6, the Menona killifish (*Fundulus diaphanus menona*) in pond 5, the northern red-bellied dace (*Chrosomus eos*) in pond 7, the western golden shiner (*Notemigonus crysoleucas auratus*) in pond 3, and both the common shiner (*Notropis cornutus chrysocephalus*) and the horny-headed chub (*Nocomis biguttatus*) in pond 4. The common shiner and the horny-headed chub were used together in the one pond as an attempt to take advantage of the symbiotic spawning relationship which occurs naturally, in some localities, between these two species (Hankinson, 1932). Various spawning devices were installed in the pond used for the blunt-nosed minnows. The number and size range of the breeders put in each pond during the spring are indicated in Table 1.

Throughout the summer the fish population of each pond was fed daily, using cooked cornmeal and oatmeal (275 pounds) mixed with bone meal (200 pounds) and clam meal (400 pounds). The 875 pounds of feed used during the entire summer represented a cost of

TABLE 2. SIZE FREQUENCIES OF YOUNG "MINNOWS" IN THE RANDOM SAMPLES OBTAINED FROM THE "SCHUIL ACRE" EXPERIMENTS

Standard length, mm.	*Hyborhynchus*		—*Fundulus*—		——*Chrosomus*[1]——			——*Notemigonus*[1]——		
	Males	Females	Males	Females	Both sexes	Males	Females	Both sexes	Males	Females
10	----	----	----	----	1	----	----	----	----	----
11	----	----	----	----	1	----	----	----	----	----
12	----	----	----	----	3	----	----	----	----	----
13	----	----	1	----	5	----	----	----	----	----
14	----	----	----	----	3	----	----	----	----	----
15	----	----	2	----	12	----	----	----	----	----
16	----	----	2	3	10	----	----	----	----	----
17	----	----	3	3	11	----	----	----	----	----
18	----	----	4	4	14	----	----	----	----	----
19	----	----	8	8	18	----	----	----	----	----
20	----	----	9	9	6	----	----	----	----	----
21	2	5	9	16	12	----	----	----	----	----
22	6	12	19	17	5	----	----	----	----	----
23	16	14	22	26	10	----	----	----	----	----
24	22	24	25	24	7	----	----	1	----	----
25	30	37	20	20	9	----	----	1	----	----
26	39	42	23	15	8	----	----	1	----	----
27	43	41	22	13	1	----	----	2	----	----
28	41	38	15	18	1	----	----	3	----	----
29	35	51	18	23	5	----	----	2	----	----
30	35	46	21	20	10	----	----	----	----	----
31	36	45	22	18	11	----	----	1	----	----
32	35	35	20	12	13	----	----	1	----	----
33	31	34	13	13	11	----	----	1	----	----
34	26	48	9	14	9	----	----	1	----	----
35	28	56	9	13	19	7	12	3	----	----
36	27	52	6	8	23	7	16	4	----	----
37	26	66	5	6	16	6	10	5	----	----
38	23	60	3	5	30	18	12	4	----	----
39	20	53	4	2	29	19	10	7	----	----
40	19	40	----	1	34	16	18	10	----	----
41	17	26	----	2	33	10	23	9	----	----
42	13	20	----	1	20	6	14	8	5	3
43	14	12	1	----	23	14	9	5	3	2
44	12	3	1	----	18	11	7	7	1	6
45	8	2	----	----	17	12	5	5	2	3
46	10	----	----	----	14	8	6	8	4	4
47	9	----	----	----	5	3	2	14	8	6
48	11	----	----	----	4	----	4	11	6	5
49	10	----	----	----	4	----	4	9	4	5
50	10	----	----	----	----	----	----	9	5	4
51	13	----	----	----	----	----	----	7	4	3
52	14	----	----	----	----	----	----	8	4	4
53	13	----	----	----	----	----	----	7	2	5
54	16	----	----	----	----	----	----	8	3	5
55	21	----	----	----	----	----	----	10	5	5
56	26	----	----	----	----	----	----	9	4	5
57	22	----	----	----	----	----	----	5	3	2
58	13	----	----	----	----	----	----	3	2	1
59	14	----	----	----	----	----	----	4	3	1
60	15	----	----	----	----	----	----	3	2	1
61	7	----	----	----	----	----	----	1	----	1
62	5	----	----	----	----	----	----	1	1	----
63	4	----	----	----	----	----	----	----	----	----
64	1	----	----	----	----	----	----	----	----	----
Total	838	862	316	314	485	137	152	198	71	71
M'n length	38.4	33.0	27.3	27.5	33.5	40.7	40.4	46.4	50.6	50.2

[1] The data for the two sexes are combined in the graph, since accurate sex determinations were impossible on the smaller specimens, and since there is no sex difference in length in the larger specimens.

$34.75. The cost of fertilizer and feed for the entire experiment was approximately $12.00 per pond.

The common shiners and the horny-headed chubs in pond 4 produced no young; throughout the entire summer there were no indications of attempted spawning. But since the water in pond 4 was

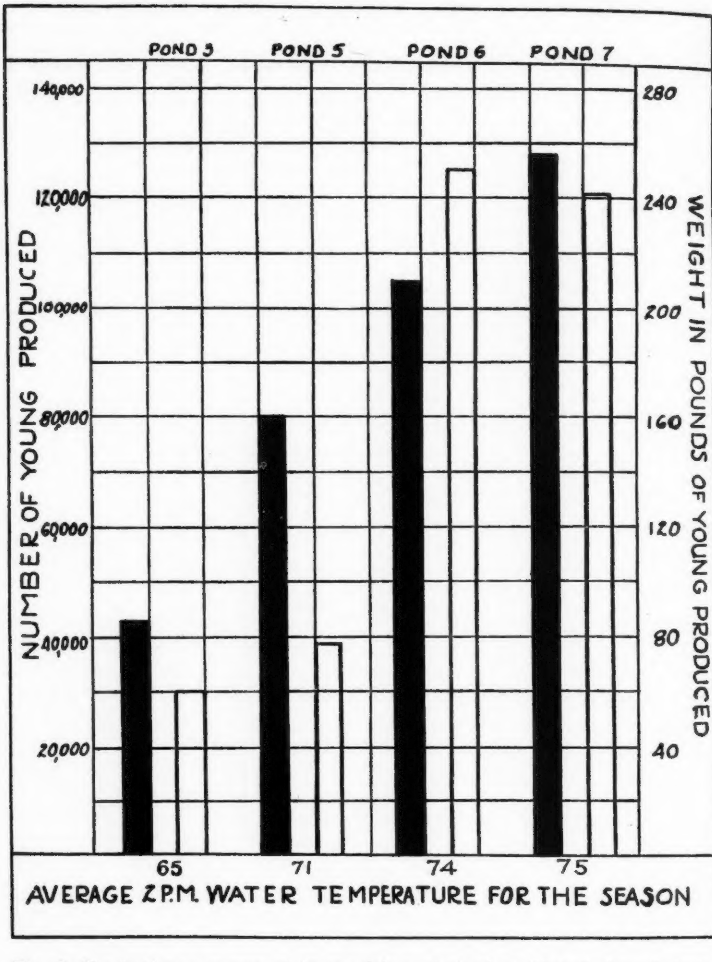

Fig. 2—Productions per acre of forage fishes, obtained at "Schuil Acres" during 1934, given in numbers (solid rectangles) and weight (open rectangles). The species involved are: the western golden shiner in pond 3, the Menona killifish in pond 5, the blunt-nosed minnow in pond 6, and the northern red-bellied dace in pond 7. Data from Table 1.

probably too cold (attaining a maximum of slightly over 60 degrees F. for only a few days during the entire summer) to permit spawning by these two species, this evidence is not sufficient to prove that these naturally stream-spawning species will not reproduce in ponds. The other 4 species were successfully propagated (data given in Table 1 and Figure 2). The ponds were drained late in the fall and a random sample from the total population of each pond was preserved for study.

The length-frequency distributions of the young minnows in these random samples are given in Table 2 and Figures 3, 4, 5 and 6. The bimodality of the length-frequency curves of the young *Hyborhynchus* (Fig. 3), *Fundulus* (Fig. 4), and *Chrosomus* (Fig. 5) produced in

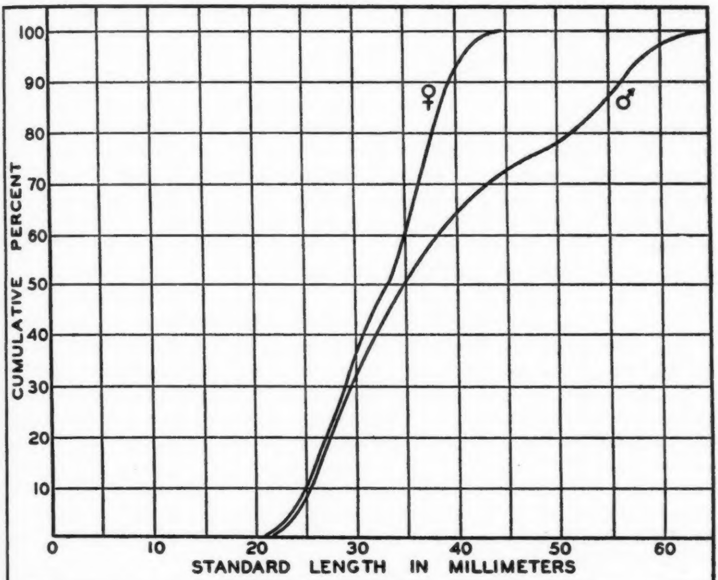

Fig. 3—Showing that the more rapid rate of growth of the males of the blunt-nosed minnow is first definitely manifest at a standard length of 30 to 35 mm. From data given in Table 2 on the length frequencies of each sex of young in the random samples taken from the Schuil Pond. These curves were constructed by plotting the per cent of the total sample of each sex which was smaller than, and included by, each millimeter of standard length. The assumption is made that the sex ratio among the young produced at various times during the season was constant.

ponds 6, 5, and 7, respectively, presumably resulted from a common cause. The most obvious explanation for this apparently abnormal bimodal size distribution is that the main spawning season of these three species, known to have occurred from the middle of June through July, was retarded considerably during the second week of July by low water temperatures (Figure 1). This bimodality is so marked in Figures 3 and 5 as to erroneously suggest two-year classes.

The wide differences in production (both in numbers and in weight) obtained with these 4 species in the 4 ponds was certainly due more to dissimilar environmental conditions in the ponds than to inherent differences in the potential productivity of the species used. The golden shiner, propagated in the coldest of the 4 ponds, gave the poorest production of the 4 species, yet in 1933 this species was propagated in a presumably warmer pond at the Schuil station at the rate of 235,000 per acre, and at a comparable rate in the warmer ponds of the U. S. Bureau of Fisheries station at Fairport, Iowa (Wiebe, 1935). The production per acre for the 4 ponds was closely correlated with the average water temperature for the season (Fig. 2), and with the relative abundance of aquatic invertebrates (shrimp, may-fly nymphs, chironomids, gastropods, etc.). The productions obtained with the red-bellied dace and the Menona killifish indicate that these species might well be added to the list of forage fishes suitable for pond propagation. It is believed that even better productions, than indicated here, can be obtained with these two species.

Other Propagation Experiments

The two spring-fed ponds (3 and 5 acres) at Highland are operated by Mr. Beach for rearing trout and propagating bait minnows. A considerable extent of warm-water shallows with abundant aquatic vegetation (*Potomogeton, Chara,* algae, etc.) in each pond provides suitable habitat for the minnows. In addition to the game fish, each pond received brood stocks of golden shiners and chub suckers (*Erimyzon sucetta kennerlii*) during the spring of 1935. Although data on the actual production of shiners and suckers in the two ponds are not yet available, it can be stated that both ponds will yield large productions of golden shiners, but relatively very poor productions of chub suckers in spite of an abundant reproduction. Mr. Schuil has had a similar experience in propagating this sucker in one of the ponds at "Schuil Acres," obtaining relatively few fish, which attained a large size during the first year.

During 1935, propagation of the northern red-bellied dace (*Chrosomus eos*) was attempted in a 0.2 acre pond at the Drayton Plains hatchery. The lack of a water supply for the pond, and the abundance of aquatic plants (*Chara, Potomogeton,* and filamentous and colonial gelatinous algae) resulted in virtual stagnation of the pond water, which maintained a slightly milky appearance throughout the summer. Spawn-

ing of the dace was observed, and eggs were found, only in a very limited part of the pond where a slight seepage of fresh water entered the pond. Water temperatures ranging from 79 degrees to 91 degrees F. were recorded during the summer. The production from this experiment was negligible. Comparing this experiment with the successful propagation of the dace in the Schuil pond, the writer is certain that the failure of the dace to reproduce in the Drayton Plains pond was due to water stagnation, and that either relatively cool or running water is necessary for the propagation of this northern, cold-water species.

A quite barren pond with an area of 0.25 acre, located in an abandoned gravel pit at Utica, was stocked with both blunt-nosed and fat-headed minnows during June, 1935. The experiment is of interest in that it demonstrates what production can be expected in a pond of very low fertility. During the season the pond produced, per acre, an estimate of approximately 100,000 very small fish weighing less than 50 pounds (a fairly good production in numbers but a poor production in weight). By August 25, only a few of the young of each species had attained a total length of 1.5 inches. At the prevailing rate of growth, few specimens would have reached maturity before their third summer of life.

Life History Observation Bearing on the Culture of Certain Forage Fishes

The following life history observations are mentioned because of their bearing on the culture of certain forage fishes. Since these observations have been made entirely on fish in Michigan waters, chiefly in the southern part of the Lower Peninsula, they may not apply in all respects, such as rate of growth, age of reaching maturity, and length of spawning season, to areas with different climatic conditions.

Blunt-nosed minnow—The habit of the blunt-nosed minnow of placing its eggs on the underside of submerged objects is well known to most fish culturists. It has been pointed out by Hankinson (1919), Hubbs (1934), and others, that objects of very diverse character are utilized. The objects, observed by the writer to contain blunt-nosed minnow nests, include boards, logs, railroad ties, rocks, boulders, bricks, pieces of crock and tile, tin cans, pieces of sheet metal such as automobile paneling, strips of bark, tree limbs and pieces of tar paper.

The blunt-nosed minnow prefers, for its nest, a flat object lying directly upon the bottom, under which the male excavates a cavity. The mud-bottomed shoals are entirely avoided by the spawning fish; the sand-bottomed shoals are definitely preferred. Nests have also been found on marl-bottomed lake shoals. Water depths of less than three feet are preferred, but the species will spawn in water as deep as eight feet if spawning facilities in shallow water are inadequate.

A single female lays from 200 to 500 eggs at one time and probably spawns 2 or more times during a single season. Actual counts have in-

dicated that the male guards nests which contain, on the average, approximately 2,400 eggs, contributed by several females. New eggs are continually added to a nest as the advanced eggs hatch. How long one of the polygamous males maintains a nest has not been determined. The spawning season extends from the latter part of May through August. The incubation period was noted as 8 to 9 days at an average water temperature of 82 degrees F. and 13 to 15 days at an average water temperature of 75 degrees F. Most attempts to hatch the eggs in aerated jars and aquaria have thus far been unsuccessful.

Among blunt-nosed minnow populations, there is a wide variation in size of fishes at the end of the first summer of life, due chiefly to the very long spawning season. Among the young reared at "Schuil Acres" during 1934 (Table 2), the greater rate of growth of the males over the females (a phenomenon first recorded by Van Cleave and Markus, 1929) was first manifest at a standard length of 30 to 35 millimeters (Figure 3).

The larger young of both sexes spawn early in their second summer of life; many of the smaller young spawn late in their second year, but it is doubtful if some of the males and females reach maturity before their third summer. The range in standard length of females with ripe eggs was found to be 40 to 65 mm. and that of breeding males was found to be 56 to 84 mm. Some fish of each sex live through four summers. These determinations, which will be treated at greater length in a later paper, do not agree well with those of Van Cleave and Markus.

Golden shiner—The spawning season of this species extends through June, July and the first part of August. The first spawning noted at the Schuil pond in 1934 was on June 6 at a water temperature of 69 degrees F. In the Beach ponds, the eggs (1 mm. in diameter) were found to be abundant in masses of filamentous algae, while none were found on the various types of coarser vegetation (similar observations are recorded by Wiebe, 1935).

Growth rate studies on 1,058 shiners from 20 Michigan localities (natural waters) show that, on the average, this species reaches a total length of approximately 3 inches during its second summer, 4 inches during its third summer, 4.5 inches during its fourth, and 5.5 inches during its sixth. In the section of the Huron River below Ann Arbor, enriched by considerable city sewage, the shiner reaches an average length of 3 inches at the end of the first summer of life. Females grow faster, attain a larger size, and live longer than males. A maximum age of eight summers and a maximum total length of approximately ten inches was noted for the species. Maturity is usually reached at a total length of about 2.5 to 3.5 inches; in localities of rapid growth, most fish mature in their second summer, while in localities of slow growth, maturity is usually delayed until the third summer. These data on the growth rate of golden shiners are given more fully in an article to appear in the papers of the Michigan Academy of Sciences.

Chub sucker—In the Beach ponds this species displayed considerable versatility in the selection of places for egg deposition. The non-adhesive eggs (2 mm. in diameter) were found scattered abundantly over large and small beds of aquatic moss (*Amblystegium riparium*), among masses of filamentous algae, and among dead grass stubble on submerged pieces of sod. The spawning season at the Beach ponds, somewhat modified by the method of handling the breeders, lasted for about 2 weeks in each pond: the first part of June in one pond, and the latter part of June and the first part of July in the other.

Newly-laid eggs were placed in aerated jars and the 5 to 6 mm. fry hatched in 6 to 7 days under water temperatures ranging from 22.5 degrees to 29.5 degrees C.

The number of eggs deposited by one female varies approximately from 3,000 to 20,000, depending upon the size of the female. Both sexes reach maturity in their third summer of life. The chub sucker is a rapidly-growing forage fish, attaining a total length of approximately 3 inches in 1 year, 5 inches in 2 years, 6 inches in 3 years, and 8 inches in 5 years.

Red-bellied dace—This small minnow, occurring in southern Michigan in the extreme southern part of its natural range, is well suited to propagation in cool-water ponds. The eggs are normally, and so far as observed, deposited entirely in masses of filamentous algae. Several times the writer observed a spawning pair or group (one female and several males) dart from one mass of algae to another, performing a short spawning embrace, of 2 to 4 seconds duration, in each mass. Subsequent examination of each algal mass revealed a few (5 to 30) non-adhesive eggs scattered through and entangled among the algal filaments. The incubation period was noted as 8 to 10 days. Dissection of females has revealed a simultaneous maturity of several hundred eggs, and the presence of at least two definite size groups of maturing eggs, suggesting that one female spawns at least twice during one season. The spawning season extends from the latter part of May into August. Maturity is reached by many individuals in the second summer of life, and some specimens live at least 3 years.

Menona killifish—In a small pond at the Lydell Hatchery, the eggs of this species were found only in masses of filamentous algae. From eggs (2 mm. in diameter) placed in aerated jars, the 6 to 7 mm. fry hatched in 11 to 12 days at water temperatures ranging from 72 degrees F. to 80 degrees F.

In some localities, both sexes mature first in their third summer of life. The females reach a larger size than the males by the third summer, but there is no sex difference in size at the end of the first summer (Table 3).

Observations on Forage Fishes Eating Bass Fry in Aquaria

At the suggestion of Dr. Carl L. Hubbs, the writer has conducted several aquarium experiments on the predation by certain species of

forage fishes on smallmouth bass fry. Some of the following observations confirm previous reports to this society; others are new.

Under experimental aquarium conditions, adult golden shiners readily ate bass fry 9, 10.5, and 13 to 17 millimeters in length, while fry more than 17 mm. (0.75 inch) long were either too elusive to be caught or too large to be eaten by the golden shiners. Blunt-nosed minnows readily devoured fry 8 and 10.5 mm. in length, and were able to catch and eat fry up to 15 mm. in length. Red-bellied dace (*Chrosomus eos*), 2 to 2.5 inches long, ate bass fry 8 to 9 mm. in length. Four to six-inch goldfish readily devoured bass fry 0.5 to 0.75 inch in length. The addition of the blunt-nosed minnow and the red-bellied dace (two species with very small mouths) to the list of forage fishes which can eat bass fry suggests that almost all minnows are able to include newly-hatched bass fry in their diet. What the various forage species do eat in natural waters and in hatchery ponds, and not what they are able to catch and devour under experimental aquarium conditions, is, of course, the important issue. Observations at the Northville Hatchery of the U. S. Bureau of Fisheries, where blunt-nosed minnows are used in bass-rearing ponds, have failed to indicate that this species consumes bass fry under hatchery pond conditions. Fifteen two- to three-inch minows seined on May 30, 1934, from pond A in which there were many fry as small as 12 mm. in length, and 36 two- to three-inch minnows seined on June 1, 1935, from pond R containing fry 9 to 12 mm. in length, contained no bass fry remains in their stomachs.

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THE SPAWNING HABITS OF THE CHUB, MYLOCHEILUS CAURINUS—A FORAGE FISH OF SOME VALUE

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Numerous reports have come to me during the last few years concerning the schooling of fish within three or four feet of the shore in the shallow water of some lakes in northwestern United States. It is said that these fish which are from eight to fourteen inches in total length, mill about the edge of the water in great numbers, at which time people rake them out by the hundreds. The fish do not appear at regular intervals on a specific beach. Instead, they may be seen once or more during the spring, at two or three-week periods. They remain inshore all day or only an hour or two, either on cloudy or clear days or even during a light rain. It was said that these great shoals appeared at various places in lakes during April, May, June, and as late as the first week in July. I owe to Mr. Heath, operator of the beautiful Sand Point Bathing Beach, located on the southern boundary of the Government Military Reservation, the opportunity to observe the activities of these fish. On June 1, 1935, at 10:45 A. M., Mr. Heath telephoned to me stating that the fish were milling about again (they had done this once before this year on May 20th) in shallow water. I arrived at the beach twenty minutes later and for the first time began to study the breeding activities of the chub, *Mylocheilus caurinus,* of Lake Washington, near Seattle.

By carefully approaching the lake shore many chubs were seen in water so shallow that their backs were exposed. At times there was great activity and much splashing; then for a minute or more they would remain quiet, whereupon renewed activity would occur. At first it seemed that the three or four hundred fish within eight feet of the water's edge and distributed along thirty or forty feet of the beach were "milling about" without any specific purpose. At twenty-five to one hundred feet intervals along the beach were other centers where the chubs were concentrated. Each of these schools upon further investigation was composed of from fifty to four or five hundred chubs. Usually from ten to fifty *Mylocheilus* were concentrated in very shallow water with their backs partly exposed. This group of fish was confined to a small area of about one or two feet in diameter, that appeared to be the focal point about which the rest of the school gathered and near which most of the activity occurred. If the entire shoal were frightened and the chubs more or less dispersed, within about five to ten minutes they would reassemble on the exact spot where previously congregated, which again became the center of their activity. Other schools in the vicinity behaved in a similar manner. Finally one large school was selected for careful study of the specific behaviors of certain individuals.

In the school thus selected, certain larger fish, the females, could be seen swimming about in the vicinity of those chubs which were concentrated at one point with their backs partially or nearly exposed. The latter group, which was more or less stationary, was composed of males whose backs were dark green and which contrasted distinctly with the females whose backs were dark brown. Many additional males, not concentrated at this one spot, were swimming at various distances off shore. If one of the off shore fish began to swim rapidly, especially one with brownish back, numerous chubs with greenish backs, the males, would start in pursuit, always crowding the female toward the shore. This pursued fish might be forced to swim right upon the fine rubble at the waters edge, so vigorous were the attentions of the opposite sex. Many times, however, before she would come near the shore, she might swim back and forth past the compact group of males, sometimes going out into the deeper water where she would become more or less quiescent for a short time. A male might be pursued by other males if he began to swim faster than the general milling around of the school as a whole. At times half a dozen or more females were pursued by numerous groups of males, a few of these often coming into the crowded group of males, whereupon much activity and splashing took place, sufficiently strong to splash water on my shoes, one and a half feet away. During this great excitement the spawning act was observed.

Once a female, with brownish colored back, was pursued by two males, and as she came near the compact group of males, five to eight others took part in the chase. The female was driven into shallow water by the males, who were crowding her continuously on the off-shore side. Although her back was exposed, she did not remain, but turned into deeper water and the chase was on again. This time she was forced on the gravel so her back was exposed, and two males pressed close on each side of her body, but no trembling or rapid vibrations were seen for she escaped into the deeper water, only to be driven back, this time into the very center of the fifty or more males concentrated in the small area. Here they were packed so close together that there was barely room for her to squeeze between them. There was a wild scramble and much splashing, the males were two and three deep as the female emerged at the very edge of the shore with only the posterior half of her body covered by water. Three males, one on each side of the female, were pressed against her body, the third was pressed closely against the body of the male on her right side. There occurred at once rapid vibrations or trembling of the bodies of these four fish in unison for about a second and a half, followed by a rest period of an equal interval, then more rapid vibrations, another rest period, and then an additional second and half of more powerful vibrations.

During each vibratory period, the tails of one or both males were

curved rather sharply over the caudal peduncle of the female which was in between them. The dorsal fin was extended in both sexes. The pectorals of the males were expanded, those of the females could not be seen. The water around their tails contained many eggs suspended for a second or two in the water, but which settled at once to the bottom during the rest periods. The milt colored the water very slightly milky. Immediately after spawning, the female broke away and swam into deeper water, where she was lost from view. The males remained for a time in the vicinity of the cluster of other males. This act of trembling was seen to occur, probably between different individuals, every few minutes during the course of the observations. The vibrations observed in the typical *spawning act* were seen now and then among the males concentrated in the shallow water when they became arranged side by side as in typical spawning.

Spawning does not always occur in the clustered group of males because numerous times females were crowded upon the rubble by two to eight males, two to four of which would arrange themselves parallel with her and press against her side, as in the case just described, then tremble or vibrate vigorously for a second or two. In each *spawning act* observed, the head of each male was slightly behind that of the female, so that his mouth was about opposite her gill opening. The tail fin of both sexes usually ended together, since the males were shorter than the females.

Both sexes are highly colored at this season. The lower lips and lower sides of their head are scarlet in color. The scarlet lateral streak is bordered above by a black lateral stripe, which separates the lower red color band from a second but fainter pink lateral streak above. The breeding female chubs average about twenty-eight millimeters longer than the breeding males. Thirty-four of the former weighed from 108 to 377 (average 203.6) grams and measured from 194 to 270 (224.6) millimeters in standard length. Twenty-five males weighed from 100 to 168 (123.8) grams and measured from 184 to 219 (197.8) millimeters in standard length.

During the time that the chubs were spawning, numerous shiners or red-sided bream, *Richardsonius balteatus balteatus,* lurked in the vicinity and at times followed closely behind the chubs, but never came into shallow water where the eggs were being deposited. *Mylocheilus caurinus* made no attempt to drive these shiners away and at all times appeared not to notice them. Once while the observations were under way, a large squawfish, *Ptychocheilus oregonensis,* rushed into the center of a shoal of chubs, the latter dispersed in great haste. This squawfish was caught by Mr. Heath with a rake and upon opening its stomach, two fish scales off a cyprinid were found. The squawfish was a female, much distended with eggs and measured about seventeen inches in total length. Although *Cottus asper* and *Cottus aleuticus* are abundant in Lake Washington none was seen in the vicinity of the eggs or around the spawning chubs.

At Sand Point, the chubs were spawning along one-fifth mile of the beach, which was composed of pebbles ranging from coarse gravel to fine rubble. The pebbles were about one-half to two inches in diameter and piled three or four deep before they were embedded in sand below. Exploration indicated that the pale greenish-gray eggs had settled among the stones to which they were firmly attached, singly and in small clusters. No eggs were found farther away than two feet from the edge of the water. No spawning was observed to have occurred except within a foot of the water's edge. Therefore, it was concluded that the eggs must have been swept out by wave action, the latter caused at times by motor boats passing a few hundred yards off shore.

Will F. Thompson, Jr., observed that chubs were spawning between 9.45 A. M. and noon on May 5, 1935, along the beach at Laurelhurst in Seattle. The next day upon examination of the shore line it was found that hundreds of thousands of light gray-green eggs were attached to the sides and bottoms of fine rubble, singly and in small masses. Thousands of eggs had been swept upon the shore above the water line and to these and the eggs adhering to the small stones were attached many grains of sand. The stones along the beach at this point (east shore of Union Bay, Lake Washington) are from one-half to three or four inches in diameter, averaging about one and a half inches. Eggs were abundant for two feet out from the edge of the shore and a scattered few as far out as three feet. Where the beach was composed of fine gravel or sand none was found, but along 350 feet of the shore line, they occurred on the stones underneath overhanging bushes as well as along sections of the beach without bushes.

The temperature of the water on May 5th was 54 degrees F. and on June 1st 64 degrees F.

The deposition of eggs in the above described habitat is unique, so far as is known to the author, because no other freshwater fish in northwestern United States selects for spawning purposes the shallow water within two feet of the shore line, where the beach is made up of fine rubble or coarse gravel. Many marine species, namely smelt, the grunion, some blennies, and a few cottoids deposit their eggs in shallow water habitats. Obviously the chub eggs are laid in a very favorable environment because: (1) The wave action insures suitable oxygenation, it keeps them free of silt, but the stones are too large to be moved about thus exposing the eggs; (2) the ova are so firmly attached to the stones that there is little danger of their being swept away and eaten by shiners or bullheads; (3) suckers do not forage in such shallow water; (4) since the eggs adhere to the sides and the under sides of stones, they are relatively free from attack by birds; (5) and upon hatching the young are afforded ideal protection among the stones. The eggs and adults on the other hand are exposed to certain hazzards: (1) The eggs and larvae might be subject to the attack of aquatic insect larvae; (2) the adults during spawning, as well as

their eggs, are easily accessable to man and animals; (3) and change in water level may cause the destruction of the eggs. Nevertheless, this habitat appears to be very successful, since the chub is one of the most abundant species of fish in Lake Washington.

Discussion

Mr. Markus: I am interested in knowing what the age of these minnows would be that are seventeen inches when they become sexually mature.

Mr. Schultz: The maximum size is about fourteen inches. We have never worked out the age and growth of the chub. We could make some guesses but they would not be of much use.

Dr. Furrow: What was the temperature of the water?

Mr. Schultz: The temperature of the water averages from 35 to 65 degrees during the course of the year. The lake never is frozen over completely, to my knowledge. The average temperature during the summer is 50 to 60 degrees. At spawning time the temperature was 54 degrees.

THE BREEDING HABITS OF THE STONE ROLLER MINNOW (*Campostoma anomalum Rafinesque*)

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The following account of the breeding habits of the stone roller minnow (*Campostoma anomalum Rafinesque*), is based upon observations made in streams forming part of the Susquehanna drainage, principally in Catatonk Creek near Candor, N. Y., and in Jackson and Newtown Creeks near Elmira, N. Y., in 1933 and 1934.

C. anomalum is essentially a migratory fish, ascending the smaller streams to spawn in the early spring. Relatively few of them stay in the small streams all year. Brightly colored males may be found as early as December, but they do not become plentiful in the smaller streams until March or early April, when they collect in large numbers in a mill-race at Candor, N. Y., where they vainly try to get above a dam. These minnows are very rare in all of Catatonk Creek above this dam which gives further proof of their migratory habit.

Spawning or nest building was observed from April 15 to June 2, 1933, in water ranging in temperature from 53 degrees F. to 75 degrees F. Hankinson (1919) recorded spawning near Charleston, Ill., from late March to May 31st at temperatures from 65 degrees F. to 80 degrees F.

The nests observed were all at the lower ends of pools in small gravel-bottomed creeks, four to ten feet wide. The water was usually about six or eight inches deep and fairly swift, but smooth. The nests may be shallow depressions in the gravel, a foot or more in diameter, or an irregular group of small pits. The digging is done entirely by the males, there usually being twenty to a hundred working at one nest. The females either skirt the school of nest-building males or lie in the deeper parts of the pools.

Fortunately it is very easy for an observer to distinguish between males and females during the spring. The males have brilliant orange and black dorsal and anal fins, and their heads and backs are thickly covered with sharp tubercles or spines. The females are drab creatures, plump and full of eggs during the spawning period.

Nest building activities were first observed on April 15, 1933, in the North Branch of Newtown Creek. A fairly compact school of about one hundred males was found at the lower end of a deep pool made by erosion around a fallen tree. The bottom consisted of rather flat stones with gravel in between. The fish were making small pits in the finer gravel, and even the flat stones had been cleaned, so there was a clean area about three feet long and two feet wide.

The whole operation was decidedly a community affair, with usually from two to five males working at each small pit, though none of them,

even the largest, ever worked at one pit long and there was constant milling activity. However, in spite of all this joint effort, there were constantly little fights going on. One of the larger males working at a pit would suddenly drive away the others near him, but by the time he got back to digging, a few other males were usually in his pit and then he might either desert the pit, crowd out the intruders, or else condescendingly work with them. If two males of the same size started a fight, it would frequently last longer. It would start with the two fish side by side over a pit; one would give the other a quick "body check" in the ribs with his spiney "shoulder" above the pectoral fins, and then the attacked fish, without giving any ground, would return the blow, and these "body checks" might be exchanged several times before one of the contestants would give up. Hankinson (1919) says that males often chase each other with such heedlessness as to throw themselves out on the shore.

The digging process consisted for the most part of merely probing down into the gravel and pushing the stones a bit. Frequently a fish would stand on its head and splash its tail out of water trying to push down into the gravel. Occasionally the larger individuals would pick up pebbles one-half inch in diameter and carry them upstream, and even small males would do the same with sand grains, but usually there was so much fighting and shoving going on that very little was accomplished by this method. Twenty minutes was the longest time that one male was seen to work at the same pit and then he did not seem to accomplish much. This was a large male who was carefully lifting pebbles out of a small pit and placing them upstream, but nearly every pebble he moved was rolled back into the pit by the current or by the tail of some other fish.

Every once in a while a fish would suddenly leave the school and leap out of water, without apparent cause or purpose, and then go back to digging with the rest.

Nest-digging operations continued all afternoon, but after sundown the school gradually got smaller, and by the time it was dark, a flashlight showed only one or two small males over the nest. For several days after these observations the stream was too high and muddy from rains to see the fish, but four days later they were seen again. The nest seemed a little deeper but otherwise everything was going on as before.

The actual spawning act was first seen at this place on April 20; though it had probably occurred before. The three or more females present did not mix with the digging and fighting males, but skirted the school or swam over it. Occasionally a female would suddenly dart down into a small pit without too many males in the way, and immediately there would be a mad scramble of three or four males trying to crowd in beside and over her. Quickly thereafter the female

would escape from under the pile of males, and then some of the males would scatter, leaving one or two to continue probing in the gravel.

This performance was observed many times during the spring and whenever a female darted down into a pit there was always much excitement among the males; sometimes eight or ten of them would be pushing and splashing their tails out of water trying to get next to her. Often I could follow the activities of one female and see her do the same thing several times so it is probable that the eggs are not all laid at one time. Occasionally a female escapes from the pit before the males have had a chance to crowd in around her and whenever this happens the males immediately stop crowding and go back to digging in their pits.

Hankinson (1919) says that as a rule one male works at a nest, and that spawning occurs by one, or occasionally two, males applying themselves to the sides of a female. The writer has seen this type of behavior at isolated pits, or at single pits late in the spring, but in the streams studied there were usually several males to each pit, and several males spawned with each female as described above.

The digging and spawning operations at each nest continued for several days. Although the nest was not seen every day, the activities at the nest discovered April 15th apparently continued in the same manner until April 23rd. On that day, after several days of cold weather, there were only about thirty males at the nest at noon, and by five o'clock these had disappeared.

Two nests were found in Jackson Creek on April 21st, when the temperature of the water was 53 degrees F. The digging and spawning activities were exactly like those described above. These two nests were watched on April 23rd, water 54 degrees F., and on April 24th, water 56 degrees F. On the 27th it turned cold and there was a frost that night, so that on the next day the water had dropped to 51 degrees F. and all activities had ceased. Diatomaceous scum, upon which Campostoma feeds, was already forming on the gravel and the rapidity with which this scum covers the stones suggests that the continual digging may keep the eggs from being smothered.

Several other nests were watched during the spring. At some of them the activities lasted only a few days, but at one nest discovered in Jackson Creek on May 18th, the digging and spawning activities were watched on May 23rd, 26th, 28th, 30th, and on June 2nd, at water temperatures varying from 62 degrees to 75 degrees F. The fish seen on the 18th may not have been the same ones which were seen on the same place on the 23rd, but I saw one battle-scarred old male there nearly every time I looked.

No nest could be found after that date but the minnows were still plentiful in the streams and could be seen feeding on the scum on the rocks. By the end of June, the males were very dull. At this time some of the riffles were dry so no fish could move downstream if they

wanted to. But on August 16th, after some heavy rains, these creeks were visited again and only a few large fish could be seen.

While watching nests during the spring, I frequently saw individuals which were blind in one or both eyes swimming around the school. Once I saw a fish with its eye gauged out but still trailing from the socket. During the course of the spring, five males and seven females were collected, each blind in one eye, and one of each sex was found blind on both eyes. That the spines of males are quite capable of doing this may be easily demonstrated by taking a dead fish in each hand and scraping the spines of one across an eye of the other.

Most of the scales on the larger fish are replaced scales with the circuli absent from the central part, and it is probable that the original scales were lost while spawning. While examining the scales to see if they could be used for age determination, it was found that the irregular light and dark blotches so typical of *Campostoma* correspond with areas of replaced scales, which were always covered with more pigment cells than the perfect ones. These observations are similar to those recorded by Langlois (1929, p. 161) for *Margariscus*. On the smaller fish, these light and dark areas are large with fairly definite borders, like the pattern on a pinto pony, but on the older fish the color is very blotchy, and it is very difficult to find scales with perfect centers.

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THE SUCKER (*CATOSTOMUS COMMERSONII*) IN RELATION TO SALMON AND TROUT

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Salmon (*Salmo salar*) and trout (*Salvelinus fontinalis*) are the most generally distributed and dominant species of fishes in the Margaree River, with its tributaries, situated in the western part of Cape Breton Island, Nova Scotia. The species next most generally abundant is the sucker (*Catostomus commersonii*). Though frequently found together, these three species did not have the same distribution throughout the river system. The salmon dominated the larger streams of the river system, particularly those with freshly formed gravel beds, resulting from the action of freshets. The trout were frequently the sole inhabitants of the smaller tributaries, whether running through forested rocky ravines, or traversing low-lying meadow lands. The suckers seemed to be restricted to the larger water courses with more or less quiet back waters.

In the main parts of the river, however, the three species were to be found in fairly close association. For instance, in the Garden pool (one of the best salmon pools on the river), the distribution during the day would be the following. The adult salmon in from the sea lay back of ledges between the main current of the pool and an eddy. The yearling salmon or parr were distributed rather generally through the deeper parts of the pool, in mid-water, near the bottom or under stones. The young salmon of the year, or fry, were in shallower water and to a great extent under stones. The trout, up from tidal waters, moved up and down in the main current, where it was of moderate strength. The adult suckers, a foot or more in length, recovering from the spring spawning, lay in considerable numbers on the bottom towards the tail of the pool. The yearling suckers moved about at moderate depths near the shore, while the sucker fry were to be seen in the very shallowest water along shore and fully exposed. It was particularly striking to find that salmon and suckers should have to such an extent the same habitat as fry, yearlings and adults. The association did not seem to be in any sense detrimental to the salmon, and one of the local guides stated that he associated suckers with good salmon fishing.

One of the relations between these fishes came to light during an investigation of this river in the summer of 1935. The suckers run up on the rapids in the spring to spawn, and by late June or July the fry are to be found in very large numbers in the eddies and quiet waters below the places of spawning. In this way the principal portions of the river system received in early summer an immense population of sucker fry. There was a very great concentration of these in Gillis' Brook, a branch of the Southwest Margaree River below

Scotsville, and on July 4th, Mr. H. C. White discovered that the salmon parr in that brook were feeding on them to such an extent that they were evidently distended and the fry came from their mouths when they were placed in formaldehyde. Yearling trout were also feeding on these sucker fry, but neither the trout fry nor the salmon fry were doing so. He has furnished the following results of an analysis of the stomach contents of these fishes, the relative volumes of the different constituents being estimated and shown as percentage.

TABLE 1. STOMACH CONTENTS OF FISHES FROM GILLIS' BROOK, SCOTSVILLE, CAPE BRETON, JULY 4TH, 1935

Fish	Length (mm.)	Food organism	Number	Volume (Pct.)
Salmon yearling	115	Sucker fry	147	100
		Ephemerid nymphs	2	Trace
Salmon yearling	130	Sucker fry	220	95
		Chironomus	6	Trace
		Coleopteran (terr.)	1	Trace
		Ephemerid imagines	4	4
		Arachids	2	1
Salmon yearling	115	Sucker fry	4	100
Salmon yearling	112	Sucker fry	100+	70
		Ephemerid imagines	5	20
		Trichopteran larva	1	10
Salmon yearling	85	Sucker fry	20+	62
		Ephemerid nymphs	8	31
		Ephemerid imago	1	
		Trichopteran larva	2	7
Salmon fry	32	Chironomid larvae	27	52
		Chironomid pupa	1	
		Ephemerid nymphs (Bactis spec.)	4	48
Salmon fry	31	Chironomid larvae	14	80
		Ephemerid nymphs	2	20
Salmon fry	29	Chironomid larvae	17	45
		Ephemerid nymphs (Bactis spec.)	3	55
Salmon fry	27	Chironomid larvae	6	45
		Chironomid pupa	1	
		Ephemerid nymphs	2	55
Trout yearling	122	Sucker fry	54	85
		Chironomid imago	1	1
		Ephemerid imagines	2	11
		Plectoptera	1	3

Just above the rapids at the head of the Garden Pool, Northeast Margaree River, there was a small cove on the south side, into which a spring-fed brook discharged, at the southwest angle. The eastern part was about a metre in depth centrally, with shallow water and stony or gravelly bottom on the river side, but for the most part with muddy bottom from which stones of various sizes protruded. Rather large stones in many places form the shoreline on the south, giving rather deep water (20 centimetres) at the very margin.

The rather rapid flow of water in the river off the mouth of the cove creates a back eddy outside the sand bar. This eddy does not greatly affect the deep eastern part of the cove, though fluctuations in the current cause movements into and out of the eastern and western

parts. The water in the eastern part of the cove differs little in temperature from the river.

The cove is not an ordinary habitat for the young of the salmon, being more suited to sticklebacks and suckers. The salmon fry, however, occur normally on the stony bottom of the shallow mouth in the eddy from the river current. Examination late in the afternoon of July 6th showed four or five salmon parr to be in the deep eastern part and to be feeding on the fry of the sucker, which were quite abundant there. Seining at dusk that evening yielded sixteen yearling salmon parr (8 to 11 cm. long) one large spent female sucker (about 40 cm. long) and three yearlings suckers (4 to 4½ cm. long). The sucker and most, if not all of the parr had entered the cove with diminishing light in the customary move to shallow water under such conditions. The next morning (July 7th) one large parr was seen in the deep eastern part of the cove and it, or a similar one, was seen near midday, and in the evening, but no others. In addition to the sucker fry, which continued to be numerous, the only other fish observed were several sticklebacks (*Gasterosteus*) and a dozen or more yearling suckers. To all intents and purposes the fish population of the eastern part consisted of the salmon parr and the yearling and fry of the sucker.

The sucker fry (from 1.2 to 1.5 cm. long) were massed against the shore, extending near the surface out a distance of about a metre. They would be along the bottom to a depth of half a metre. They were quite constantly in motion horizontally and at random in every direction. They constantly kept apart from each other a distance of from three to ten centimetres.

The parr itself (apparently about 11 cm. long), though roaming at times, had one main station, and another subsidiary one, both in the deep water. The former was about two metres from the shore and was characterized by having a rounded stone, on one side of which the parr could rest, inclined at an angle of about 30 degrees from the horizontal, with the head up and directed toward shore.

In this position the parr faced the moving mass of sucker fry against the shore and near the surface and would be carried to them by a movement straight ahead. Its feeding was carefully observed from 6.30 to 7.06 P. M., July 7th. At more or less regular intervals it made quick dashes to the margin of the mass of suckers, usually at the surface, which it broke, but occasionally near the bottom. It could not be seen whether the dash was or was not successful, but in some few cases, it was repeated before return to the station, as if the first attempt had been unsuccessful. Ordinarily there was very prompt return to deep water, with more or less leisurely resumption of the station, and occasionally a wandering to the outer part of the deep water or a change to the other station. On one occasion the parr rested for a time on the flat bottom in a distant portion of the deep water.

During the half hour it went to the subsidiary station twice, failing

to feed from that position the first time, but making two feeding dashes the second time. The feeding dashes during the period, including two abortive ones, in which only half the distance was traversed, were twenty-five during a period of twenty-six minutes, that is one every minute or somewhat more.

Each dash of the parr to the margin of the mass of sucker-fry caused movement of the outermost ones toward the shore, and also toward the surface, frequently affecting the surface film, though the fry never broke through the film. On the morning of the 8th at 6.30, the parr was not in evidence, and the fry had extended their distribution outward a half a metre or more near the surface with the bottom distribution little altered.

The distribution of the sucker fry in the cove out from shore over rather deep water was correlated with the projection from the bank over the water of branches of alders. Such a situation resulted in a somewhat ideal distribution of the sucker fry for the parr to feed upon them. In successive days the single parr (a smaller one occasionally came into the cove, but was never seen to feed) continued to feed upon the sucker fry whose numbers steadily diminished. While sandpipers were sometimes seen on the shore of the western part of the cove and may have been taking the fry there, no other enemy of the fry in the deep eastern part than the single parr was seen for some days. Night conditions, however, were not followed, and there is the possibility that the fry to some extent moved out of the cove, though there was nothing to indicate that such occurred. The 8th of July was cool and dull, with the water temperature lower, and the parr was, when observed, never seen to feed so frequently as above described. With higher temperatures on the 9th rapid feeding was again observed in the late afternoon and evening. By that time the mass of fry had diminished so that the zone occupied was only about 30 centimetres wide. A rough calculation showed that even a liberal estimate as to the number consumed by the parr (8 hours at the rapid rate) would not account for the whole reduction in numbers of the fry.

With the latter restricted to a narrower shore zone, the parr changed its procedure slightly. It occupied more or less in succession three different station from which to make its dashes at the mass of fry. One of these was centrally placed about a metre shoreward of its former main station; another was similarly advanced shoreward from its former subsidiary station; and a third was about equally distant from the central one and on the other side. From these three the stretch of shore related to the deep water was fairly effectively covered. Also instead of merely picking up individuals from the fringe of the mass of fry, the parr would at times quite reach the innermost and shallowest parts tenanted by the fry along this strip of shore. The inclination of the parr from the horizontal while resting at these stations seemed greater than previously, which would be necessitated if the parr directed itself toward the main mass of the fry.

Towards midday on the 11th in bright sunlight, two trout, 15 centimetres or more long, entered the cove and left it repeatedly, either singly or together. One sometimes rested under the shade of the alders, but usually they swam about, covering the shallower portions of the cove quite thoroughly and in doing so where the sucker fry were known to be present, on the outer side of the eastern end over the central sand bar, were quite evidently feeding. Their roamings extended into the shallow western part, where they likewise fed. They showed themselves much more wary than the salmon parr, leaving the cove when I moved about so little as not to disturb either the large parr feeding at my very feet, or two other smaller parr equidistant from me with the trout, and seemingly recent entrants into the cove.

The smaller parr always failed during these days to adopt the shore feeding habit of the large one, but appeared to pick up objects from the bottom in the outer part of the deep portion. When maintaining a station, they were practically horizontal in position, a short distance above the bottom and facing the shore.

The large parr continued to be seen feeding in characteristic fashion on the sucker fry as late as July 13th, but was not seen after July 16th, when it was resting on the bottom in deep water. The sucker fry seemed to change but little, if at all, in abundance after July 11th, but their numbers were doubtless increased by others coming in, as well as decreased by their enemies. On July 16th and again on July 22nd, smaller parr were seen roaming about the cove, near the bottom, and when near the shore apparently picking up the salmon fry, but not by making dashes.

Outside of the somewhat temporary situation at Gillis' Brook, sucker fry, even at the height of their abundance, were only found as minor constituents of the food of the salmon parr. It cannot be claimed, therefore, that they form a particularly important source of food for the young salmon. While they last, however, they make a valuable contribution to the diet of trout as well as of young salmon. As they do not compete with these fishes for food, they may be considered as making available to these salmonoids food stuffs that would otherwise go elsewhere. The yearling suckers are suitable for kingfishers and doubtless act thus as a buffer to the young salmon and trout. Since in waters like those of the Margaree River, salmonid fishes seem to be the chief devourers of the young suckers, a great abundance of suckers would be expected to accompany any considerable reduction in the numbers of these sport fish, and might be considered as symptomatic of such reduction.

OBSERVATIONS ON THE GROWTH OF ATLANTIC SALMON PARR

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The observations reported in this paper were made during a study of the Atlantic salmon parr in certain rivers of the Maritime Provinces of Canada between the years 1930 and 1934. For conciseness certain phases in the growth of the parr are presented in the form of answers to questions. The data upon which these answers are based are included in the accompanying table which records the length of the parr of the several rivers at one, two, and three years of age.

The young salmon, which is known as a parr, spends the first years of its life in its native river, leading an existence somewhat similar to that of the trout. The duration of its river life varies from two to five years, depending upon its environment. When it is about five inches in length it acquires the silvery characteristics of the smolt and leaves the river for the sea, where it remains one, two, or three years before it returns for the purpose of spawning.

1. DO THE PARR OF A RIVER SHOW UNIFORM GROWTH?

In general, most small rivers because of their relatively short course have a uniform environment throughout their length. Consequently the environmental conditions which determine the rate of growth of the parr tend to be fairly constant. Unless radical changes in topography occur within a narrow range or there is a superabundance of lakes, the parr of a small river show but little variation in growth and are more or less distinctive of the particular river, since the rate of growth determines size, form, and smolt age. The distinctive character of growth in the different rivers is shown in the accompanying table.

Large rivers, on the other hand, often present radically different environmental conditions, both in the main stream and in the tributaries. These diverse conditions produce marked differences in the growth of the parr in the various sections, and demonstrate that a uniform rate of growth is unusual in a large river, as may be seen by comparing the growth in the different parts of the Restigouche and Margaree River systems. In the Restigouche system the growth of the parr in the Upsalquitch River, a spring-fed forest stream with a limited food supply, is much slower than that of the parr in the Matapedia River, a valley stream with a better food supply. Likewise, growth in the upper part of the Matapedia River, a relatively sluggish lake-fed stream passing through farming country, is faster than in the lower part, which flows rapidly through more woodland than farming country. An even

more striking illustration of the difference in the growth of parr in sections of the same river is found in the moderate-sized Margaree River, which has two main branches. The larger branch, the Northeast Margaree, in its upper part is a swift mountainous and woodland stream and in its lower part flows through a wide valley with open farmland. The smaller branch, the Southwest Margaree, has its source in a large body of water, Lake Ainslee, and flows its entire length through the same type of country as the lower Northeast Margaree. It differs from the Northeast Margaree in having a six to seven degrees Fahrenheit higher water temperature during the summer and in receiving a large supply of plankton-bearing lake water.

2. What Factors Determine the Rate of Growth of the Parr?

The salmon rivers recorded in the accompanying table comprise three main types: (1) the spring-fed mountainous river of cool water flowing through woodland with a scanty food supply; (2) the slowly flowing valley river of moderate water temperature flowing through open farmland with a good terrestrial and aquatic food supply; and (3) the river fed by lakes and swamps with considerable vegetation and abundant terrestrial and aquatic food. The rate of growth of the parr increases in the order mentioned and, although influenced by a multitude of complex and little known constituents including climate, season, volume of water, and other environmental conditions, depends mainly upon two closely related factors: (1) food and (2) temperature. Inasmuch as a warm water temperature favors the production of food, it is impossible to determine their separate effects. Temperature affects metabolism; if too low, it retards and if too high, it inhibits the feeding activities of the parr. Within limits, the growth of the parr is practically proportional to the abundance of the food supply, as may be observed in the fast growth in the lake-fed rivers, the fairly rapid growth in the valley rivers, and the slow growth in the mountainous streams, e.g., the Southwest Margaree, the lower Northeast Margaree, and the upper Northeast Margaree.

3. Does the Size of the River Affect the Growth of the Parr?

It is generally recognized that the larger specimens of the same species of fishes are found in large bodies of water. This rule does not uniformly apply to the growth of salmon parr, since the size of the river is of secondary importance to its type. However, in very small rivers the rate of growth varies with the size of the stream. In the small rivers of Cape Breton, such as the Grand, Inhabitants, Tillard, Middle, Black, and Scott, the rate of growth is directly proportional to the size of the stream. Likewise, the growth of the parr is faster in the Margaree River than in its little tributaries or in the small neighboring rivers. If the volume of water is too low, growth is retarded during the summer droughts; e.g., the rate of growth in the Scott River, which has a low water level in summer, is slower than in the

Tillard River, a slightly larger stream which flows through the same country. The abundance of food for the first year parr is often sufficient to give as good growth in the small rivers as in the large, but the supply of food for the older parr is usually inferior, resulting in slower growth in the small rivers. Certain rivers, such as the Moisie, because of a scarcity in the smaller food forms may even show slow growth during the first year and good subsequent growth.

4. Do Lakes Influence the Rate of Growth?

Certain salmon rivers have their origin in lakes, pass through lakes in their course, or receive lake water through tributaries. Almost invariably the lake-fed rivers have more rapidly growing parr than the rivers without lakes. The parr of the Southwest Margaree River show more rapid growth than those of the Northeast Margaree River; the parr of the Grand River with its source in the large Loch Lomond are larger than those of the Inhabitants River, a neighboring stream of similar size; the parr of the lake-fed Upper Matapedia River are larger than those of the Lower Matapedia River; and the largest parr in our collection are from the lake section of the Medway River above Greenfield, Nova Scotia. It appears that the presence of lakes affects the growth of the parr chiefly through the temperature and the food supply, although it doubtless involves other complicated environmental factors.

5. Are the Parr of a River of Uniform Type?

Since the rate of growth determines duration of river life, size, and even form, the parr of different rivers have a more or less characteristic appearance. The uniform growth in the small rivers produces a relatively consistent type, as determined by age, size, and configuration. In the large rivers of varied environment the marked difference in the growth of the parr in the various sections results in a diversity of types. Consequently the only uniformity of type which can be said to exist in large rivers is that of the predominating section.

Although the chief differences in the appearance of the parr of the various rivers are the result of the rate of growth as determined by environment, the problem of distinct river varieties is still unsolved. If the variations resulting from growth are eliminated, little evidence for distinguishing racial differences between the parr of different rivers exists. The acceptance of the parent stream theory in its entirety assumes a uniformity of type for the parr of each river, which is the result of hereditary as well as environmental differences. If the parr develop into adult salmon which return to their parent stream, they must possess at least some sort of characteristic type. Since many rivers possess a diversity of types, in order to support the parent stream theory it is necessary to adhere to the somewhat dubious proposition that each section of a river is an individual unit, to which its parr return as adult salmon for spawning.

6. Do the Parr of a River Have a Uniform Smolt Age?

The age at which the young salmon leaves the river is determined by the rate of growth. In the small rivers a relatively constant environment produces a uniform rate of growth and a fairly consistent smolt age, which is more or less characteristic for each river. On the other hand the varied environment of the different parts of the large rivers tends to produce smolt of different ages; e.g., there is a difference of nearly one year in the age of smolts between the Upper Northeast branch and the Southwest branch of the Margaree River, and between the Upsalquitch River and the Matapedia River of the Restigouche System.

GROWTH OF SALMON PARR IN SMALL AND LARGE RIVERS

Rivers	Length in Millimeters at Years of Age 1	2	3
Small rivers—			
Bonaventure	45	79	113
St. John (Gaspe)	41	65	86
Dartmouth	44	75	109
York	46	77	109
Grand (Cape Breton)	62	112	162*
Inhabitants	58	105	152*
Tillard	58	95	133*
Middle	53	102	151*
Black	45	81	117
Scott	45	75	105
Large river systems—			
Restigouche			
Little Main Restigouche	44	80	117
Kedgwick	43	78	113
Patapedia	46	79	113
Upsalquitch	45	75	105
Upper Matapedia	53	98	144
Lower Matapedia	47	87	126
Matapedia	50	92	134
Margaree			
S. W. Margaree	65	140	......
Lower N. E. Margaree	58	110	......
Upper N. E. Margaree	50	91	132*
Small tributaries of N. E. Margaree	50	95	140*

*Theoretical growth, if parr remained for three years; no actual measurements made.

THE USE OF FISH MEAL, COTTONSEED MEAL, MEAT MEAL, SALMON EGG MEAL AND DRIED SKIM MILK IN TROUT DIETS

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Due to the constantly increasing price of meat products during the past year, it seemed imperative that substitutes be used in feeding the trout in New York State Hatcheries. This spring a trial of such substitutes was started at the State Hatchery in Gloversville, N. Y., to determine what foods would be selected to replace the meat diets.

Four of the diets used were recommended by the Experimental Hatchery at Cortland, N. Y. One commercial product—Hewitt's Special Small Trout Food—was also used. The control lot was reared upon a one hundred per cent meat diet. The fish used were brook trout (*Salvelinus fontinalis fontinalis*). The eggs were obtained from the Paradise Brook Trout Co., Cresco, Pa., and were hatched and reared until the start of this experiment at the State Hatchery in Rome, N. Y. The fish started feeding on February 7th. As is the ordinary practice in a production hatchery, the fingerlings, at least during the early stages, were fed about what they would eat, the level being held about the same for the different lots. Each group was held in six wooden rearing troughs, two series of three, each trough having a capacity of about eleven cubic feet of water. The average water temperature during the time of the experiment was 51 degrees Fahrenheit; the average for each day varying from 42 degrees to 56 degrees.

The composition of the diets employed is listed in Table 1.

TABLE 1. COMPOSITION OF DIETS IN PARTS BY WEIGHT*

Diet No.	Beef liver	Hog melts	Dried skim milk	White fish meal	Salmon egg meal	Cotton-seed meal	Meat meal	Commer-cial food	Salt
1	50	50	----	----	----	----	----	----	----
1S	49.5	49.5	----	----	----	----	----	----	1
E1	12.5	12.5	25	25	----	25	----	----	----
E2	12.5	12.5	25	----	25	25	----	----	----
E3	12.5	12.5	25	----	----	25	25	----	----
E4	12.5	12.5	25	25	25	----	----	----	----
E5A	12.5	12.5	----	----	----	----	----	75	----
E5B	20	20	----	----	----	----	----	60	----

*The sources of the various diet ingredients with their respective prices are as follows
Beef liver—from various packing companies—average cost $0.111 per pound.
Hog melts—from various packing companies—average cost $0.039 per pound.
Dried Skim Milk—spray process—from Crowley's Milk Co., Albany, N.Y.—$0.0775 per pound.
Salmon egg meal—from Neptune Fish Products Co., Inc., Seattle, Wash.—$0.08 per pound.
Cottonseed meal—41 per cent protein—purchased locally—$0.028 per pound.
Meat meal—Darling's Meat Crisps—from Darling & Co., Buffalo, N. Y.—$0.0397 per pound.
Commercial Food—Hewitt's Special Small Trout Food—From Edw. R. Hewitt, 127 E. 21st St., New York, N. Y.—$0.102 per pound (plus freight).

It will be noted that Lot 1 was the control fed half and half beef liver and hog melts. Diets E1 to E4 are the Cortland Diets, each

containing 25 per cent of meat, the other 75 per cent being made up of three constituents. Each of them contained 25 per cent dried skim milk, the spray-process type being used because of the binding property. The first three each contained 25 per cent cottonseed meal, the remaining 25 per cent of each being, respectively, white fish meal, salmon egg meal, and meat meal. The fourth diet contained in addition to the meat and dried skim milk 25 per cent each of salmon egg meal and fish meal. The commercial fish food was used on two lots; on 5B according to the instructions of the producer, namely with 40 per cent meat and with a daily food allowance of 1-5-1.0 per cent body weight (dry basis). Lot 5A was fed at the same level and with the same meat supplement (25 per cent) as Diets E1-E4. One per cent of salt was added to the meat diet for the remaining group, 1S.

Since the results obtained with diets containing dry meals depends to a great extent upon the mixing and feeding, our procedure will be cited. First we made up what we called "stock mixtures" of Diets E1-E4; prepared simply by mixing the same quantities of each of the three dry foods. For example, 200 lbs. of dried skim milk, 200 lbs. of white fish meal and 200 lbs. of cottonseed meal would give 600 lbs. of the stock mixture for Diet E1. Then the desired quantity of this stock mixture was weighed out and the 25 per cent meat and the water added. This should be thoroughly stirred and allowed to stand at least over night so that it has time for absorption of water. It should be emphasized that the amount of water added should be given a great deal of consideration, as the consistency determines to a large extent the amount of food the trout will take and the waste. If too little water is added, the feed is so hard that the fish have difficulty eating it; if too much is added, the waste is excessive and the pollution of the water is increased. Especially with a set-up like ours where a series of ponds is fed with water which has already passed through a series of troughs, considerable pollution results at best; so the consistency has to be constantly checked.

The trials were conducted during the period April 9th to August 12th. The data was calculated at the end of each two-week period and an average made of the results of the nine periods included. The data thus obtained is presented in Table II.

The general trend of the results of these experiments are briefly as follows:

The control lot fed beef liver and hog melts proved to be the most expensive diet used with the exception of the commercial fish food. The growth rate of the control lot was no better than that of the dry feed—meat diets, in fact not equal to that of several. Although the mortality was somewhat higher on the dry feed lots, it was not sufficient to cause concern. The Cortland Diets all proved satisfactory; but of the four, the two containing salmon egg meal gave superior growth at the lowest costs. It might be well to repeat what these

TABLE 2. RESULTS OBTAINED FROM USE OF DIETS LISTED IN TABLE 1
Data Averaged by Two-Week Periods (18 Weeks Total Time)

Diet No.	Pounds food (wet basis) per pound trout gained	Food cost per pound trout gained	Weight fish per cubic foot water	Per cent mortality	Per cent gain in body weight
1	4.0	.33	2.3	.4	38
1S*	3.4	.24	3.1	.2	38
E1	3.6	.19	2.1	.8	37
E2	2.9	.20	2.4	1.0	43
E3	3.5	.20	1.9	1.3	36
E4	2.7	.18	3.0	.9	45
E5A**	5.3	.40	1.8	4.6	40
E5B	2.7	.30	1.3	2.5	17
	Extremes of Data in Computation of Averages				
1	3.5-5.2	.28-.38	1.1-3.2	.06-1.6	23-51
1S	2.7-3.9	.19-.28	1.9-3.8	.06-1.0	29-50
E1	2.4-4.2	.14-.24	1.0-3.2	.1 -4.9	21-60
E2	2.3-3.7	.15-.26	1.0-3.5	.07-3.6	27-63
E3	1.9-6.5	.10-.36	1.1-2.1	.1 -4.8	17-52
E4	1.9-3.4	.13-.24	1.0-5.0	.08-3.9	31-59
E5A	4.3-5.8	.22-.55	1.0-2.2	.2-27.0	26-53
E5B	1.0-8.5	.11-.93	.8-1.3	.5-10.2	3-35

*Last ten weeks only.
**First ten weeks only.

diets were. One contained equal parts by weight of meat, dried skim milk, salmon egg meal and cottonseed meal; the other equal parts of meat, dried skim milk, fish meal and salmon egg meal. Of these two, the latter produced slightly better results. Regarding the commercial food used, we found that when the trout were allowed an amount sufficient to produce gains comparable with that of the other lots, at the end of ten weeks the mortality had become so excessive that it was necessary to discontinue the lot. When it was fed at the recommended low level, it produced an entirely unsatisfactory growth. We found that the addition of one per cent salt to the meat diet resulted in a lower cost of production; the rate of growth was not materially affected.

Since the dry meals gave satisfactory results from the start of the experiment on, we may conclude that fish from one and one-half inches on may be successfully fed these rations. Our experience also indicates that no concern need be felt in changing abruptly from a meat to a dry food diet, as we have noted a resultant acceleration rather than a retardation in growth.

Most of the New York Trout Hatcheries have already adopted the use of one or two of the better dry feed diets listed. It is expected that at least 150 tons of the dry meals will be used in the State Hatcheries during the fiscal year.

Discussion

Mr. Fiedler: May I ask Mr. Deuel whether the different diets were selected purely on the ground of their cost, or on the ground of their nutritional value?

Mr. Deuel: What we are interested in is both the cost and the growth obtained from these diets.

Mr. Wales: Ordinarily we feed meat with a dipper. I was wondering how this mixture was fed.

Mr. Deuel: It is impossible to feed these mixtures with a dipper. Right

from the start of the experiment we fed these fish by hand. We find that the fish take the food very well from the hand. An effort was made to break up the food as much as possible with the hand so that it would not be too large.

DR. HUBBS: Several of us are interested in knowing just what that commercial fish food was that you mentioned.

MR. DEUEL: It is Hewitt's Special Small Trout Food.

MR. TUNISON: The cost of the food is not as important as the results obtained. Take, for instance, salmon egg meal that runs eight cents a pound as compared to, say, fish meal which costs only around three cents; the point to be considered is not so much the price of the food as the results that you get from it. In the case of the salmon egg meal you may get your money back in fish flesh produced. It may therefore be that the most expensive food is the most economical.

THE USE OF SALMON BY-PRODUCTS AS FOOD FOR YOUNG KING SALMON

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INTRODUCTION

The fish food problems of the Pacific Northwest are in many ways uniquely different from those found in other sections of the country. The Pacific salmons are the principal forms reared. The young of these, after hatching, are held in retaining ponds and fed only until the time of migration. The time of migration varies with the species, but, generally, the young fish start for their feeding grounds in the sea long before they reach a size comparable with trout as they are reared in the East. Under such conditions the amount of food consumed by the individual fish is not large, but considering the millions of fish raised the total food bill makes up a large part of the annual budget.

The bodies of the spawned-out salmon and the by-products from the canneries that pack the fish caught before reaching the spawning beds provide a tremendous quantity of potential food materials for the young fish.

This series of experiments is an attempt to measure the effect of the various methods of preparation upon the resultant food values of some of the major salmon by-products as food for young salmon.

EQUIPMENT AND METHODS

The fish used in this group of experiments were derived from eggs of king salmon (*Oncorhynchus tschawytscha*) spawned at the Auburn State Hatchery, Auburn, Washington, and hatched at the University of Washington Experimental Hatchery, under identical conditions. With the completion of the yolk sac stage each lot of 3,000 fish was counted out and confined to a standard hatchery trough provided with a separate inflow of water. The water fluctuated in temperature from 40 degrees Fahrenheit to 48 degrees Fahrenheit, with the average at 44.7 degrees Fahrenheit.

The experimental diets were used from the very start of the feeding period. Feeding started about four days after the yolk sac scar had healed and each diet was continued without change for the duration of the experiment, or twelve weeks' time. The fish were fed all the food they would consume without waste.

At intervals of two weeks three samples of 100 fish each were taken from each experimental lot for weighing to compute the average weight

*The assistance of H. Baltzo, M. Lobell, T. Martin, F. Scheel and J. Wilson of the School of Fisheries in carrying on part of this experiment is gratefully acknowledged.

TABLE 1. SUMMARY OF EXPERIMENTAL FEEDING OF SALMON BY-PRODUCTS TO YOUNG KING SALMON
(ONCORHYNCHUS TSCHAWYTSCHA)

Date experiment started, January 14, 1935. Concluded, April 7, 1935 (12 weeks).
Initial number of fish per trough, 3,000. Average water temperature, 44.7 degrees F.

Trough No.	Diet	Initial length av. cms.	Final length av. cms.	Per cent gain	Initial av. wt., grams	Final av. wt., grams	Per cent gain in wt.	Condition factor	Mortality No.	Per cent mortality	Total food in grams	Efficiency factor	Lbs. of food per lb. fish	Cost per lb. of fish
A	30% liver, 70% sal. meal	3.49	5.68	62.8	0.54	2.40	344.4	1.31	59	2.0	4,181	1.31	.76	$0.053
AA	50% liver, 50% sal. meal	3.49	5.65	61.9	0.54	2.32	329.6	1.29	71	2.4	5,495	0.95	1.05	0.074
B	30% liver, 70% com. d. s. meal	3.49	4.29	22.9	0.54	1.07	98.1	1.36	111	3.7	3,582	0.43	2.33	0.09
BB	50% liver, 50% com. d. s. meal	3.49	4.53	29.8	0.54	1.37	153.7	1.47	96	3.2	5,190	0.46	2.17	0.103
C	30% liver, 70% can. sal. flour	3.49	5.49	57.3	0.54	2.17	301.9	1.25	102	3.4	15,666	0.30	3.33	0.117
CC	100% can. sal. and flour	3.49	4.81	37.8	0.54	1.38	155.6	1.24	108	3.6	13,197	0.18	5.56	0.111
D	100% canned salmon	3.49	4.41	26.4	0.54	1.13	109.3	1.32	123	4.1	11,997	0.14	7.14	0.143

Liver—Fresh beef liver @ $0.07 per pound.
Sal. meal—Air dried chum salmon meal @ $0.07 per pound.
Com. d. s. meal—Commercial dried salmon meal @ $0.025 per pound.
Can. sal. and flour—Canned spawned out chum salmon plus $.5 pound of flour per seven-pound can of salmon @ $0.02 per pound.
Canned salmon—canned spawned-out chum salmon @ $0.02 per pound.

and then returned to the trough. These results were plotted in Figure 1 to give the weight increase curves.

Foods Used

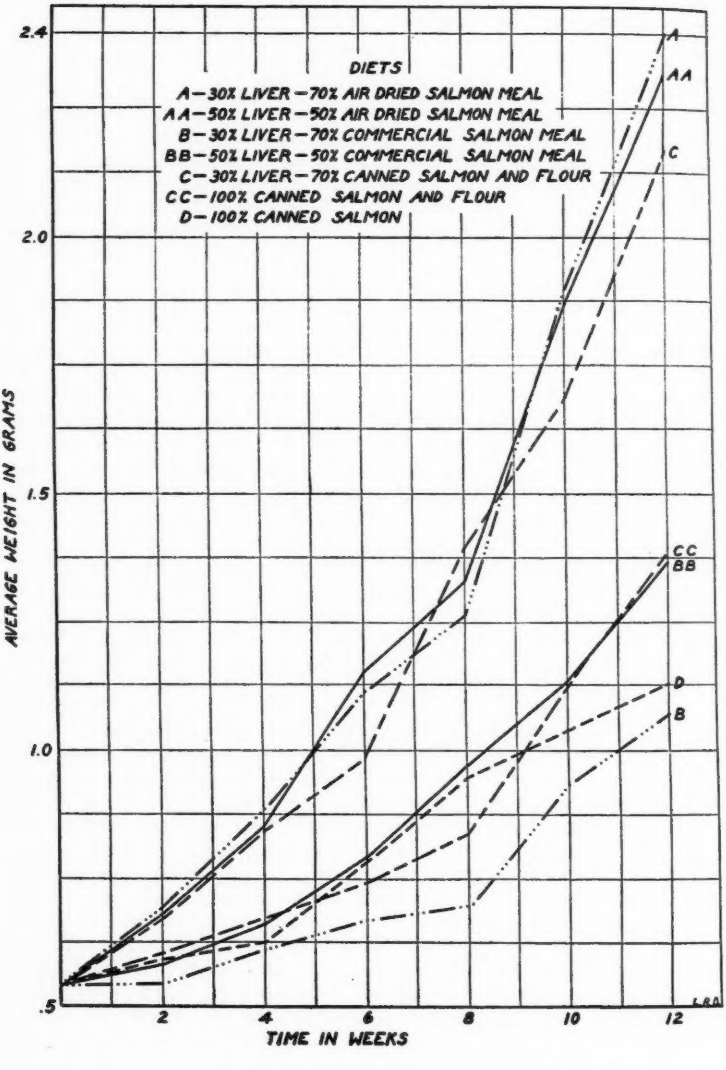
The foods used in this experiment to form all or a portion of the diets are some of the so-called by-products of the salmon industry. A number of other possible foods might have been included in this study but lack of space prevented their consideration at this time.

The fresh beef liver used in diets A, AA, B, BB, and C, Figure 1 and Table 1, was purchased locally and ground to a fine pulp before it was mixed with the other ingredients. For figuring the cost to produce a pound of fish, Table 1, a cost of $0.07 per pound was used for the liver in the various diets.

The air dried salmon meal used in diets A and AA was prepared from the spawned out carcases of chum salmon (*Oncorhynchus keta*). In the preparation of the meal the fish were chopped into large pieces. A short cooking period followed, which was accomplished by immersing the pieces of fish in hot water until the protein coagulated. The cooked flesh was ground through a food chopper and then dehydrated in a current of warm air (120° F.). The time required for complete drying was from twelve to sixteen hours. The dried fish was then ground to a fine meal and mixed thoroughly with the liver portion of the diet without the addition of water. In feeding, a quantity of the mixture was weighed out and placed in a flour sieve which divided the particles of food into the correct size for the young fish. For computing the food costs an estimate of $0.07 per pound was used for air dried salmon meal.

The salmon meal obtained from Mr. R. W. Harrison, U. S. Bureau of Fisheries, and used in diets B and BB, Figure 1 and Table 1, was a commercial product available on the market at a cost of about $0.025 per pound. It was the best grade of the commercial meals obtainable. The meal was prepared by dehydrating the viscera, etc., wastes from the canneries, in a steam jacketed dryer, temperature probably 300 +° F. The commercial salmon meal was mixed and fed in the same manner as the air dried salmon meal.

The canned salmon used in diets C, CC, and D was prepared by the State of Washington, Department of Fisheries, from the spawned-out carcases of chum salmon. This food was sealed in tin cans holding approximately seven pounds. Each can of salmon used in diets C and CC had one-half pound of low grade flour mixed with the fish prior to cooking, while the canned salmon used in diet D contained only the ground salmon. Both types of canned salmon cost $0.02 per pound. The canned salmon and the liver used in diet C were thoroughly mixed together and then whipped to include air which caused it to float on top of the water when fed. The canned salmon used in diets CC and D was also whipped causing it to float where the pieces could be torn apart and eaten by the fish.


DIETS
A—30% LIVER—70% AIR DRIED SALMON MEAL
AA—50% LIVER—50% AIR DRIED SALMON MEAL
B—30% LIVER—70% COMMERCIAL SALMON MEAL
BB—50% LIVER—50% COMMERCIAL SALMON MEAL
C—30% LIVER—70% CANNED SALMON AND FLOUR
CC—100% CANNED SALMON AND FLOUR
D—100% CANNED SALMON
AVERAGE WEIGHT IN GRAMS
TIME IN WEEKS
2.4
2.0
1.5
1.0
.5
2
4
6
8
10
12
A
AA
C
CC
BB
D
B

Discussion

The growth rates as illustrated by the average increase in weight, Figure 1, showed a distinct division of the experimental lots into two groups. The first group composed of the following diets produced the fastest rate of growth, lot A 30 per cent liver and 70 per cent air dried salmon meal, lot AA 50 per cent liver and 50 per cent air dried salmon meal, and lot C 30 per cent liver and 70 per cent canned salmon and flour mixture. Those in the second group, lot CC fed 100 per cent canned salmon and flour, lot BB fed 50 per cent liver and 50 per cent commercial salmon meal, lot D fed 100 per cent canned salmon, and lot B fed a diet of 30 per cent liver and 70 per cent commercial salmon meal, grew at a rate that was average, or only slightly below, for the species under the temperature conditions, but decidedly below the growth produced by those in the three more rapidly growing groups.

The length-weight relationship as expressed by the condition factor, Table 1, ($\text{C.F.} = \dfrac{\text{Average weight} \times 100}{\text{Average length } 3}$) would indicate that the fish in each lot were about normal for the species.

The marked superiority of the air dried salmon meal over the commercial salmon meal as a food for young salmon, shown by lots A and B, and lots AA and BB, would indicate that the composition of the meal and its method of manufacture are important. The fish fed the air dried salmon meal, lots A and AA, not only grew very rapidly but their utilization of food was very high as indicated by the high efficiency factors, Table 1, column thirteen, and the low value of the poundage of food to produce a pound of fish. This high utilization of food made it possible to produce the large fish in the air dried salmon meal groups at less cost per pound of fish than was the case in any of the other groups although the purchase price of the food material was less for the other foods used. This reduction in cost to produce a pound of fish was even more outstanding when compared with the cost of a straight beef liver diet. Under similar conditions a minimum of 3.2 pounds of liver are required to produce a pound of young salmon, or at $0.07 per pound for the liver the cost would be $0.024 to produce a pound of fish as compared with $0.053 and $0.074 for the diets containing 70 per cent and 50 per cent, respectively, of the air dried salmon meal. Some part of this extra growth and utilization can no doubt be accounted for by proper sizing, mixing and feeding methods, but these factors can only be partly responsible as indicated by the reduced growth rate, Figure 1, higher cost per pound and greater mortality, Table 1, of the two lots fed with diets containing 70 per cent and 50 per cent commercial salmon meal, although cared for in the same manner as those fed the air-dried meal.

Of the three diets, C, CC, and D, in which the canned carcases of the spawned-out chum salmon composed a part or the entire diet, the

growth produced by the combination with factor H contained in the 30 per cent beef liver which was mixed with 70 per cent canned salmon and flour, lot C, proved to be superior to the 100 per cent canned salmon with flour diet, lot CC, and very much superior to the fish in lot D that received 100 per cent canned salmon. The cost per pound of producing the fish on diets C and CC was approximately the same, $0.11 per pound, although the fish in lot C that received the 30 per cent liver supplement increased 301.9 per cent in weight as compared to an increase of 156.6 per cent in weight for the fish in lot CC fed the canned salmon and flour mixture as a straight diet.

The fish in lot D fed 100 per cent canned salmon recorded the poorest growth of any of the lots with the single exception of lot B fed 30 per cent liver and 70 per cent commercial salmon meal. The mortality in lot D was the highest of any of the experimental groups with 128 of the original 3,000 fish, or 4.1 per cent dying during the twelve week experimental period. The efficiency factor was lower and the pounds of food required to produce a pound of fish was higher 6.14 and 7.14, respectively) than on any of the other diets. The cost of the food was only $0.02 per pound but the cost of producing a pound of fish was $0.143 or greater than any of the other foods or combinations of foods used.

These results would indicate that some of the salmon by-products, which are at present wasted or only partly used, have a decided value as food for young salmon when properly prepared and combined with other foods.

Summary

The value of a number of salmon by-products, as straight diets or combined with liver, as food for young salmon, were compared by experimental feeding.

The combinations of air dried salmon meal and beef liver produced very rapid growth with lowest mortality rate and the minimum of cost for the fish produced.

The steam dried commercial meal and liver combinations proved to be inferior to the special processed air dried salmon meal and liver combinations in promoting growth.

The addition of 30 per cent liver to a canned salmon and flour diet to provide factor H proved to be very beneficial in promoting growth without increasing the cost of the fish produced when compared with a 100 per cent canned salmon and flour diet.

The mixing of a coarse flour with the spawned-out fish before canning increased the growth rate and reduced the cost of producing the fish when compared with a diet in which the flour was not added.

Discussion

Mr. Foster (Washington): I would like to ask Mr. Schultz to point out on that graph the difference between the diets fed with seventy per cent air

dried salmon meal and thirty per cent liver and the seventy per cent commercially dried salmon meal and thirty per cent liver.

Mr. Schultz: "A" is thirty per cent liver and seventy per cent air dried salmon meal; "B" is thirty per cent liver and seventy per cent commercial salmon meal.

Mr. Foster: As I understand it, the commercial salmon meal was manufactured at a much higher temperature than the air dried meal?

Mr. Schultz: Yes.

Mr. Tunison: What was the source of the commercial meal?

Mr. Schultz: I cannot answer all the questions that may be asked because I did not carry on these experiments. Perhaps Mr. Foster could tell you; he is very familiar with the work.

Mr. Foster: I do not know where it came from. It was recommended by Mr. Harrison, technician of the Bureau, as the best commercial meal on the market. He may have made it himself.

Mr. Fiedler: Does the author have a chemical analysis of these two kinds of meals?

Mr. Foster: I think not.

OBJECTIVES IN THE POND CULTURE OF SALMONOID GAME FISH

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Game fish propagation in the Province of British Columbia is being undertaken by the Dominion Department of Fisheries and the Provincial Game Department and many of the scientific and experimental issues in connection with this work are being investigated by the Biological Board of Canada, under the Minister of Fisheries. Since fish are now being raised in ponds on a fairly extensive scale it seems important that the underlying requirements and objectives of pond culture should be kept clearly in mind.

A good opportunity for studying the details of pond cultural operations was afforded when the Biological Board volunteered the scientific supervision for the introduction of the brown trout on Vancouver Island. A large proportion of the fish were reared to the fingerling stage in ponds at Cowichan Lake, under the Dominion Department, and at Qualicum Beach, under both the Provincial and Dominion Departments. The broader aspects of pond cultural operations, presented in this paper, have been drawn largely from the experience gained in the production of these fish.

When Is Pond Culture Necessary?

The Biological Board has recommended that before a body of water is stocked a scientific survey should be made, so that, if planting is necessary, a definite program based on specific requirements can be formulated. Such a survey preceded the stocking program drawn up for the Kamloops district which was reported in the Transactions of the American Fisheries Society in 1932. The results obtained so far from this procedure have been extremely satisfactory and the Dominion Department of Fisheries is now providing funds for a number of additional surveys.

From the data collected by the biological survey it can be determined whether stocking is necessary and, if so, what species would be most suitable and whether fry or larger, pond-reared fish should be planted. In arriving at the final decision that fish larger than fry should be planted, at least four things need to be taken into consideration. These things are: the mortality due to predators, including cannibalism; the relative cost of production; whether the supply of fry is limited and whether the planting is to be used for scientific purposes, such as a life-history study.

The Mortality Due to Predators

It is almost impossible to place too much emphasis on the magnitude of the losses that occur after fry have been planted in a body of water that already contains a stock of larger fish and it seems to be in the best interests both of the public and of the fish culturists to point out that the excellent results normally obtained in stocking barren lakes is not the usual expectation when restocking depleted waters. It is customary for the authorities to publish statements of the thousands of fry planted in such waters but, at the same time, they give no indication of the number of fish expected to survive to the legal size. In fact, the work is usually carried on without any knowledge of how many fish are produced because experimental evidence along this line is extremely scanty.

A valuable set of data for guidance in stocking with fish of various sizes has been drawn up by Dr. Embody. His figure for the expected survival from fry plantings has been verified rather closely by the Biological Board's investigations at Paul Lake. Dr. Embody's data, slightly modified, are shown in table 1.

Table 1—Showing the percentage of fish of different lengths at the time of planting expected to survive to a size of six inches, based on data supplied by Embody.

Length in inches	1*	2	3*	4	6
Percentage expected to survive to a size of six inches	5	35	60	80	100

*Fry are considered to be one inch long and fingerlings three inches.

For the present this table must be accepted as being fairly typical of the normal survival in nature up to a size of six inches. It is conceivable that under certain conditions, for instance where there is an unusual abundance of predatory fish, that the data might not fit the case, but it is probably sufficiently accurate for fishery administrators to adopt as a working model. It would certainly aid the advancement of fish culture if a number of authorities could be persuaded to follow a standard procedure with regard to stocking policy. In British Columbia the size of the seeding recommended for lakes is 200 fry per acre. The term "seeding" includes the natural production of fry plus the planting. In places where larger fish are being planted it is being advised that the number of fish required be obtained from the scale of equivalent survival values as shown in table 1. In the latter case an estimate of the number of fry and fingerlings produced naturally must also be included in the calculation.

On the basis of the information in table 1, it would take approximately 200 fry, or seventeen fingerlings to produce ten six-inch fish. In other words, in stocking a body of water it would take approximately 12 times as many fry as fingerlings to obtained the same result. The act of gaining a greater survival by protecting the fish in ponds

until they reach a larger size might be defined as "stepping up the survival value."

The amount which the survival value of a given quantity of fry can be stepped up by pond retention depends, of course, on the normal mortality in the ponds during the process. Barring losses from unusual causes, such as accidents and epidemics, and with a vigorous stock, it should be possible to raise at least 70 per cent or eighty per cent of the fry to the fingerling stage. With a rather weak stock of brown trout about 71 per cent of the fry were reared to a size of three inches at the Qualicum Ponds in 1934. In this case with a given quantity of fish to start with the survival was stepped up, not to twelve times its original value, but to approximately nine times.

In the majority of cases, however, the fishery manager wishes to know how many fry or how many fingerlings would need to be planted in order to produce a certain head of legal-sized trout. If the objective is 50,000 six-inch fish, it could be attained with 1,000,000 fry or 83,000 fingerlings. In order to obtain 83,000 fingerlings the pond cultural operations should be started with about 115,000 fry. These values depend, of course, on normal expectations.

The Cost of Producing Fish in Ponds

There is another side to the question which is often overlooked by anglers when urging the planting of fingerlings and that is the relative cost of producing fry and pond-reared fish.

When fry are being handled in large quantities they can be produced for about $1.50 to $2.00 per thousand. The cost of the 123,000 three-inch brown trout produced at Qualicum Ponds in 1934 was about $3,000 or about $24.00 per thousand. This amount includes wages, fish food, the cost of 170,000 fry at $1.75 per thousand and a proportion (one-tenth) of the cost of constructing the ponds.

If the 123,000 brown trout produced at Qualicum in 1934 were equivalent in survival value to 1,500,000 fry, then it would have been cheaper to plant fry at a cost of $2,600 if they had been available. In this particular case fry in such large numbers were not available and, in order to achieve the objective, pond-rearing was the only solution for the problem.

From the few data available on the subject the estimated costs for fry and fingerlings given above seem to be fairly typical of the relative costs of production. If this is the case there seems to be nothing to be gained by pond culture if enough fry can be obtained for the project under consideration. The argument has also been advanced that the survivors in nature from fry plantings are better than pond-reared fish in both game qualities and edibility. It would seem to be better, therefore, unless there are other circumstances to be considered, to plant fry and allow for the large, expected mortality. This statement must be modified when there is a shortage of fry or where it is de-

sired to carry out scientific studies by marking the fish. These two points will be treated below.

The Procedure With a Limited Supply of Fry

Owing to the numerous requests for fish for restocking purposes the number of fry available is usually inadequate. Too often an attempt is made to satisfy every claim for recognition and when results fall to materialize fish cultural operations as a whole fall into disrepute. The fact is being recognized in British Columbia that it is impossible to stock all of the waters satisfactorily with the present facilities. It has been suggested that this difficulty might be overcome by an "area system of fish culture" whereby certain restricted districts could be built up with adequate plantings for a period of four years, then the facilities could be used to restock the next area requiring attention. Even under this system the quantity of fry required may not always be available and the increased survival value obtained by planting fish larger than fry might be necessary in order to obtain enough fish to insure an adequate planting even though the costs would be 10 per cent to 15 per cent more.

In the case of the rainbow trout of the interior of British Columbia, the Kamloops trout, it is possible to get enough surplus fry at a very low cost from the hundreds of lakes that dot the country to supply the needs for this species, but in the case of the rainbow and cut-throat trout of the coast region the difficulties of collection are so great that it is almost impossible to get sufficient quantities of eggs. Furthermore, in the coast region, where the runs are drawn out for several months and high water conditions make the employment of extra help necessary in order to obtain the parent fish, the cost of fry production is much higher than the average. If the cost of fry exceeds $2.00 per thousand or if fingerlings can be produced for less than $20.00 per thousand then pond-rearing would seem to be justified from the economic standpoint.

Pond-Rearing as an Aid in Scientific Studies

In order to formulate efficient regulations it is necessary to have a complete set of data on the migration and life-history of the various populations of fish. The only way to do this scientifically in places where the populations from various drainage systems mix, as they do on the British Columbia coast, is to establish definite marks of recognition by fin-clipping. In order to do this work efficiently the fish should be larger than two inches to permit handling. If fish of the right size cannot be secured in nature they must be raised in ponds. The extra cost entailed would therefore be chargeable to research.

One of the specific problems that marking is being used to elucidate is the question of the identity of the migratory (sea-run) and non-migratory types of rainbow trout. It has always been a controversial

question as to whether the progeny of the non-migratory rainbows might become migratory, and also whether the migratory rainbows (steelheads) might produce a certain number of offspring which lived entirely in fresh water without ever going to sea. It is obvious that it is impossible to legislate for the protection of these two types without accurate information about their life histories.

Another problem is the question of the distinctness of the early and late runs of salmon. Problems of this type can be most readily attacked with aid of the marking technique. A marking program for the runs of spring salmon of the Cowichan River is being initiated to find out where these fish migrate to in the sea, where they are caught on their return journey, to what extent they may wander to other streams than the parent one and whether early running fish produce offspring which also run early.

Pond cultural operations for the purpose of obtaining scientific information, such as that indicated above, must be prosecuted on a fairly large scale in order to furnish the required data. If these operations are combined with a program to build up depleted runs, then the cost of producing the fish would be chargeable to both the fish cultural project and to research. The extra costs would, therefore, seem to be a justifiable expense.

Immediate Objectives in Pond Cultural Operations

When the decision has been reached that pond cultural operations are necessary then the order for the specified size and number of fish required can be turned over to a practical fish culturist. Before starting out to fill the order the fish culturist should consider, among other things, five important objectives:

The first is to make the most efficient use of the pond space. The number of ponds for fish cultural projects is limited and ordinarily the expense of operation, apart from the cost of fry and food, remains the same whether the ponds are filled to optimum capacity or not. It was demonstrated at the Qualicum ponds that by grading methods the large fish could be taken out as they reached an average size of three inches. By this method, in a pond system comprising five ponds each with a capacity of 3,000 Imperial gallons of water and a flow at the season of lowest water of fifteen gallons per minute, 123,000 three-inch brown trout were produced in a period of ten months. In order to obtain the maximum use of the ponds it is possible to utilize them for two species in the same year. If the ponds are used first for the fry of fall-spawning fish they can be later turned over to the production of the progeny of spring-spawning species. This procedure has been adopted at the Cowichan lake ponds but it requires a good deal of planning and manipulation on the part of the fish culturist.

The second objective is the attainment of the average size required by the project, usually within a specified length of time. If growing

conditions are good in the ponds for the species under consideration then there will probably be little need for forcing the growth. In many cases, however, there will be a necessity to plan the attainment of the predetermined size. It has long been known that up to a certain point the higher the temperature the faster the growth, consequently by selecting a pond site with a water supply having a temperature favouring optimum growth better results could probably be realized. Preliminary experiments have indicated that light-coloured ponds and night feeding will favour faster growth. In order to realize this objective it is important to keep an accurate record of the rate of growth. A study of the accuracy of sampling with a hand dip-net was carried out at the Qualicum ponds in connection with the rearing of the brown trout mentioned above. It was found that samples taken with the dip-net from point to point in each pond gave a value for the average length of the fish about 5 per cent lower than that obtained when a random sample was taken as the 84,000 fish remaining in the ponds were hand-counted out at the time of planting. This means that the fish are actually larger than the average indicated by dip-net samples; however, this error is on the right side.

The third goal in pond culture should be to produce the fish of the required size with as little variation around that average as possible. If a three-inch size is specified and the variation is great, there is not only a danger of cannibalism among the fish themselves, with a consequent lowering of the efficiency of production, but the survival value in nature may also be lowered. In the Qualicum project the fish in one of the ponds were kept as a control and were not graded. Although the fish produced in this pond were about the same in number and size as the average for the four graded ponds the variation in size was considerably greater. An important feature of this experiment was the evidence that cannibalism had occurred in the pond of ungraded fish but not in the graded ones. When the fish in the ungraded pond were counted out about 12 per cent of them were missing. It is probable that cannibalism occurs when the largest fish are about three or four times the size of the smallest ones. About 5,000 of the small fish from one of the ponds were placed in a screened-off section on July 26 and were given special care until October 1. These fish averaged 3.4 cm. on July 26 as compared with an average length of 4.2 cm. for the fish in the pond from which they were selected. On October 1 they measured 6.1 cm. as compared with a length of 6.2 cm. for the fish in the main pond. In a similar experiment carried out during the winter period (Nov. 1 to Mar. 1), however, the small fish failed to catch up in size. It is apparent that if the small fish are graded into a separate pond early enough in the summer that they can be induced by special care to catch up to the larger fish. This procedure will undoubtedly prove to be an important aid in the production of fish of a uniform size.

The fourth objective is to raise the fish to the required size with as little mortality as possible. An important factor in the success of pond cultural work is to have a stock of large, healthy fry to start with. It has been observed that eggs from large, good-conditioned females are better for pond cultural operations than eggs from undersized fish. It is possible that a great deal of the mortality experienced in pond cultural work could be overcome by a strict selection of the parent stock. Nevertheless the actual operations require care, cleanliness and an exact record of the losses from day to day. Assistants must have a special aptitude for this type of work; unless they are keenly interested it becomes mere routine and fish culture is as yet far from being a routine job.

Finally, the fish produced should be healthy and vigorous in order to meet the competition for food and to avoid enemies when planted. If a planting of diseased fish is made it may not only diminish the survival value expected, thereby invalidating the work, but it may also involve the risk of spreading undesirable diseases in watersheds that do not contain them. In British Columbia any mortality of an unusual nature is investigated immediately by a consulting pathologist who keeps in close contact with the fish cultural operations.

Conclusion

The general tendency in British Columbia for the past few years has been to place fish culture on a more scientific basis. An encouraging feature of this movement has been the sympathetic attitude on the part of anglers and others interested in the sport fisheries. They are beginning to realize that in order to have good fishing a certain head or abundance must be maintained and that if the fish cultural problems are attacked with this objective in mind there is a good measure of assurance that a satisfactory solution can be reached. The Biological Board's investigations, sponsored by the Dominion Department of Fisheries, have already produced satisfactory results in the few places where they have been applied. The surveys of watersheds, the area system of fish culture, the stocking programs based on definite requirements and the nutritive capacity of the water, and the more efficient pond cultural technique based on the criteria of optimum capacity, specified size and rate of growth, minimum variation, low mortality and good health should serve to increase the efficiency of fish cultural operations.

THE TULSA MUNICIPAL FISH HATCHERY AND PROBLEMS OF POND FISH CULTURE

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A detailed account of the early history of fish propagation by the city of Tulsa would require much space and time, neither of which shall be given in this discussion. Suffice to say, that immediately upon completion of the reservoir which was constructed to supply the City of Tulsa with sparkling Spavinaw water, steps were taken to provide facilities for rearing a continuous supply of game fishes. Through the cooperation of the State Game and Fish Department and the Tulsa chapter of the Izaak Walton League, one large rearing pond was built at Spavinaw, and two small ponds near the city in Mohawk Park. These ponds were stocked annually by the State Game and Fish Department with bass fry, and the fingerlings were planted in Spavinaw each fall. The great number of fishermen who took advantage of the wonderful facilities there made it necessary to enlarge the fish rearing units. A few years later four new ponds were built at Spavinaw by the combined efforts of the city of Tulsa and the State Game Department. Thus, did the city find it necessary to engage the services of a fish culturist to attend the nurseries and look after the general stocking of the lake, and reservoirs.

In the early spring of 1931, I resigned from the service of the State Game and Fish Department, to take up this work for the city of Tulsa; we began at once to enlarge our activities. After a careful study of the situation it was decided to locate the main hatchery ponds in Mohawk Park on account of the space available, the character of the soil, low cost of pond construction and the water supply.

Our first year's activities consisted of securing a stock of brood fish of all kinds, which were secured from near-by lakes, and by hook and line from Spavinaw. During our spare time we managed to build eight new ponds by using a tractor and fresno borrowed from the street Department. No outside labor was used, and the necessary pipe was obtained from salvage stock of the Water Department; pipe that was no longer useful for high pressure duty in the city distribution system. The Park Department had previously built an eleven acre circular lake in Mohawk Park to be used for swimming and other recreational purposes. This was later abandoned, so we took advantage of the situation and installed a supply line and suitable outlet, and converted the lake into a bass rearing pond. This gave us a total of fifteen ponds with a combined area of nineteen acres. The output of fingerling fish the first season was 223,000.

The following season additional brood fish were obtained so that it was not necessary to draw on the good nature of the Game and Fish Department for bass fry. We were able to produce an abundance of fry from our own stock. During the winter of 1932-33 a new highway was routed through the park past the hatchery location. This highway called for considerable grade past the place, and of course necessitated the borrowing of considerable dirt. We managed to persuade the engineering staff of the Park Department that ordinary bar-pits would be unsightly along this road, and suitable ponds could be constructed by carefully planned excavation. The plan worked, thanks to the good nature of the park engineer, and the C.W.A. officials and we were presented with nine nice new ponds. Likewise, a series of ponds on the East of our location were added by C.W.A. labor during the course of construction of a recreational lake which adjoins the hatchery on the East. So by one means or another we have built up our system to thirty-three ponds with a total area of thirty-three acres of water.

I wish to say now that we are indebted to all concerned for the splendid cooperation, and for the approval of projects in this construction work. The several city administrations, the park Superintendent, C.W.A. officials, F.E.R.A. Administrators, and all the city water department officials, under whose jurisdiction our work is carried on. Every one of them have taken active part in the development of this Division of Fish Culture, as have the local sportsmen for which Tulsa has long been famous. I wish also to say that we are not alone in this desire to provide good angling for our citizens. Everyone likes to fish, and no form of recreation reaches the rank and file, or contributes to the health and happiness of our nation as does just plain fishing. I believe municipal fish culture is here to stay. I believe any city that owns a reservoir of any size can find the means to maintain a fish hatchery. Once stocked with "tackle-busting" bass, few citizens will ever complain that a municipal reservoir is a burden on the public. There are many ways by which a fish hatchery may be made useful, and of interest to the general public. Once it is established Mr. Citizen will fight for its continuation.

We have hundreds of visitors each holiday, some are interested in water itself, others, in the various forms of life in the water, some are plant hobbiests; aquatic vegetation is always an interesting topic. Botanists, entomologists, and nature lovers of every category make our hatchery their laboratory for field study. We encourage science students of our public schools and university to use our facilities. We supply our citizens with gambusia minnows for the asking to place in mosquito infested pools. Needless to say, we are called on from every angle to advise, encourage, and administer aid regarding lily ponds, fish ponds, and aquaria pets of all descriptions. We accept all this as an expression of interest on the part of the public and respect their inquiries accordingly.

As most of you perhaps know, all money collected for boating and fishing fees on municipally owned reservoirs in Oklahoma, must be used for restocking or improving such reservoirs. A charge of twenty-five cents per day for residents, and fifty cents per day for non-residents is charged at Spavinaw lake. This money is put aside as a hunting and fishing fund, and is used to finance the hatchery. We believe this fair and equitable to everyone concerned.

Our latch string is always out to anyone who desires whatever information we are able to give. Many municipalities have sent delegations of sportsmen and councilmen to our hatchery for advice and information. The City of Pawnee sent its fish pond attendant over here for two weeks during the spawning season to learn first hand the manner of handling bass fry. We are happy to be able to assist others who are interested in this work. Judging from the calls we have, I believe a training school for fish culturists, such as many State Departments operate would be a valuable addition to Oklahoma's activities. We are ready to assist the State in any way we can with such an undertaking. The large number of lakes and reserviors under construction in Oklahoma will necessitate the training of more men to keep abreast of the demands for fishing facilities.

Our methods of propagating fish at the Tulsa Municipal hatchery differ somewhat from that of State and Federal hatcheries due to several factors. Namely, limited finances, shortage of help, and mainly, because our finished product is planted in waters all ready containing a great many adult fish. For these reasons we are interested in producing an abundance of fish as economically as possible, with minimum labor, and have the fish as large as possible at planting time.

We have tried many methods over a period of years, and observed closely the results as compared with other reports given in the transactions of this Society. We have used several methods this season, in regard to rearing largemouth bass, and the results can best be seen by visiting the hatchery. Our ponds were used in various ways especially for your observation during this meeting. I am sorry weather conditions have been such as to make it impractical to drain some of the ponds so that accurate check could be made at this time. The results will be available later to anyone desiring them.

I do not know what weather conditions did for bass culturists in other parts of the country last spring. We experienced the most upset situation in our memory. Bass began spawning on April twenty-first, the water temperature at that time was sixty-four degrees F. Many of these eggs began hatching on the twenty-eighth. Evidently they were deposited a few days before we noticed them, as the water was quite roily all spring due to excessive rain. Cold weather returned on May fourth, and continued for a week which lowered the water temperature to fifty-two degrees. It continued to

fluctuate in this manner through the entire month of May. Our bass continued to spawn at intervals with each rise and fall of temperature until May thirtieth, consequently we have bass fry of all sizes from eyed to one inch fish. It was necessary to distribute the fry to separate ponds according to their sizes as best we could. How successful we were will no doubt be learned when we drain the ponds this fall.

Some of our experiments have been to rear bass in nursery ponds fed only with forage minnows, red-fin minnows, and golden shiners. All forage minnows were introduced after the fry were one inch long. This has worked out quite satisfactorily in our case. Other ponds were fed forage minnows along with ground fresh meat, and dry shrimp. Still other ponds were fed nothing but dry shrimp and ground meat with no forage minnows. Our best results are obtained from ponds well supplied with aquatic vegetation, stocked with forage minnows after the bass are well past the danger zone, and the feeding of shrimp and mash throughout the summer. Last season the rearing pond in which we used this combination produced 14,800 five-inch bass per acre, while the average from ponds in which only forage minnows were used produced 4,000 bass per acre of the same size. In the pond which contained no vegetation, the bass were fed mash and shrimp only, and did not produce over 2,000 fingerling bass per acre; however many of these were ten inches long. All ponds were fertilized early in the spring with an average of six hundred pounds of sludge per acre. Daphnia were abundant in all ponds at the beginning of the season.

We left several of the late spawns in the brood ponds with the adult bass last season. The adult fish were fed beef and pork melts daily, and no cannibalism was noticed. Four ponds used in this manner produced 5,000 each of three-inch fingerling bass, an average of 10,000 per acre. These three-inch fingerlings were very even in size, evidently very little cannibalism among them during the summer.

The cost of melts and liver took such a rocketing ride this last spring that we decided to try substitutes for feeding adult bass. After considerable experimenting with various mashes, and methods of preparing it, we arrived at a food that so far has given us very good results. The main item, protein, is supplied from tankage, or meat scraps. There are several meals that can be used such as corn meal, cotton seed meal, soy bean meal, shorts, etc. We have had best results with equal parts by weight of tankage, corn meal, and cotton seed meal. We add six pounds of the mixed meal to ten pounds of boiling water, and cook about one hour in a double boiler. Then smoothe the mash out in shallow cookie pans which have been sprinkled liberally with dry ground shrimp. Then we sprinkle the shrimp over the mash after the pan is full. This prevents the top surface from cracking as the mash hardens. We let

the pans of mash cool over night. They may be turned over on a board and the pans removed in the morning. The slabs of mash can be cut into any desired size. To avoid the chunks sticking together we churn or roll them in shrimp meal. The feed is then ready for use. The cost of this food prepared is less than two cents per pound.

The shrimp used in rolling the chunks of mash, not only makes the feed more palatable to the bass, but some of it is always washed off in feeding. This provides food for the fingerlings which soon learn to follow the adult bass at feeding time. I have not seen an adult bass eat a single fingerling this season. The main objection to this mash is that the adults go for it so violently they bruise themselves, by running into each other. Care must be taken to scatter the feed as much as possible to avoid these collisions, and at the same time scatter the shrimp for the fingerlings. Our adult bass are apparently in good condition after a season on this diet. We invite the suggestions of dietitians to advise ingredients that will improve the feed. I believe it has possibilities, and perhaps we can include cure-alls in the mixture for internal parasites, week-end hangovers, etc.

We use this same mixture of mash for bream. They take to it very readily and during the summer grow rapidly. Just what rate of growth may be expected has not been worked out as yet. However efforts to grow them through the winter have not been satisfactory. They eat very little during the cold months, and no noticeable growth is made from December to March. Adult sunfish take the feed as eagerly as the young. By stall feeding last season our ponds produced 34,500 blue-gill per acre. These fish were from one to two inches long.

As stated early in this paper our main object is to keep down expenses. The production of all species could no doubt be increased in our hatchery, if we had additional funds for the purchase of feed. We in Oklahoma are far from the commercial fisheries and consequently fishery by-products are not available at practical prices. We are trying to produce fish with home-made feeds in such a manner that any municipality may do likewise with limited funds.

Our hatchery production last season was as follows.

The twenty acres used for rearing largemouth bass yielded 108,000 fingerling fish, average length five inches, and an average of 5,400 per acre.

Ten acres used for bream yielded 345,000, or an average of 34,500 per acre, one to two inches in length.

Three acres used for crappie culture produced 28,000 two-inch fish, an average of 9,330 per acre.

Total all species 481,000.

Total cost of feed for season $92.49.

THE DISPERSAL OF FERTILIZING SUBSTANCES IN PONDS

O. Lloyd Meehean

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In a previous paper to this Society (Meehean, '35) an attempt was made to show the importance of an all animal cycle in the ecology of a pond. In that publication evidence was produced to show the relationship between the production of unicellular organisms and zooplankton, also including chironoids.

Samples taken in ponds, especially with reference to Oklahoma and Louisiana, have revealed that phytoplankton is of minor importance as to volume and numbers. This year, in a paper presented to the Louisiana Academy of Science (Meehean, '35), data was presented to show the relative importance of plankton constituents in bass ponds as measured by their organic content.

The relative importance of zooplankton and phytoplankton, as determined by the difference of the total dry deposit of the filtrates from No. 25 bolting cloth and the centrifuge as compared with that of the whole water, was not beyond the limit of error for the method used and was therefor not measurable.

On the other hand, the dry residue from the whole water in these fertilized ponds averaged 215 mg/l whereas the residue from the Berkefeld filter averaged 202 mg/l. This difference in weight was made up of bacteria and non-centrifugable debris taken out by the filter. Birge and Juday ('34) found a mean average of 43 mg/l in the water of Wisconsin lakes. Since the phytoplankton and zooplankton are unmeasurable and the filtrate from the Berkefeld filter showed a decided loss of weight, it is safe to assume that bacteria play an important part in the stabilization of organic fertilizing substances and in the ecology of the pond.

Waksman and Carey ('35) state, "The function of bacterial activities in the transformation of organic matter in sea water is shown to comprise two distinct processes: (1) the decomposition of organic matter, resulting in the liberation of at least part of the elements in forms (CO_2,NH_3,PO_4) available for diatom and algal nutrition; (2) the assimilation of some of the dissolved substances and their transformation into bacterial cells, which in turn can be used as sources of food for marine animals." The substances attacked in this food-getting process are organic materials which are the only source of carbohydrates that provide the necessary energy for bacterial multiplication.

We have evidence from a number of sources that carbon oxidation is the first stage in the breakdown of organic substances. For in-

stance, Mohlman and Edwards ('31) found that there is a direct relation between the five day biochemical oxygen demand and the ratio of organic carbon.

Waksman and Carey ('35) showed that sixty per cent of the carbohydrate is oxidised to liberate energy and that forty per cent is utilized for the synthesis of cell substance. He also showed that the decomposition of glucose depends upon the presence of nitrogen. Most of the nitrogen is probably bound up in cell substance and at first goes to make up the fauna of the pond. This would be reflected in the ratio of carbon to nitrogen in the bottom as compared with that in the fertilizer used. It is also indicated by the fact that the second stage in the biochemical oxygen demand curve is accompanied by the evolution of nitrogen products, resulting, probably, from the breakdown of live cell substance. He shows that inorganic nitrogen may be used and that organic compounds may be broken down to provide an adequate source of nitrogen.

Kreps ('34) found that the bottom in the vicinity of decaying organic matter has a bigger flora than at other places. Waksman, Carey, and Reuszer ('33) state that bacteria causing decomposition are more active in mud and that there is a parallelism between bacterial development and the evolution of carbon dioxide which is derived from the oxidation of carbon in organic substances.

The evidence is therefor pretty strong to show that carbohydrate, such as is supplied by organic fertilizers, is used as a source of energy for bacterial multiplication and that at least a part is tied up temporarily as cell substance. It shows that nitrogen is necessary for the formation of these cells, and that nitrogen may be derived either from organic or inorganic source. Fertility cannot be maintained through the use of commercial fertilizers alone since carbohydrate material is indispensable to bacterial activity in the pond.

Cottonseed meal carries carbon and nitrogen in the ratio of approximately 40:1. In the soil a ratio of 20:1 indicates a fair supply of organic matter but if the ratio should be as low as 10:1 or less, decomposition, and consequently bacterial activity, is low.

In ponds fertilized with varying amounts of cotton seed meal, the ration of C/N in the bottom reached 20:1 where fifty pounds of fertilizer was used each week and dwindled down to 9.6:1 in ponds where only twenty pounds was used. Samples taken in newly constructed ponds gave a ration of 22.6:1 on the topsoil used to form the embankment and 7.9:1 on the newly stripped bottom. One pond, fertilized with commercial 5:15:5 mixture at the rate of forty pounds per week, showed a ratio of 9.3:1 indicating a low decomposition rate and consequent low bacterial activity. Waksman ('33) found a ratio of 10:1 in the sea.

These figures in no way reflect the amount of carbon and nitrogen on these bottoms but there was a variation between 0.04 per cent in unfertilized ponds to 0.15 per cent in the most heavily fertilized.

This is 50 per cent lower in the unfertilized ponds than is found on poor sand and in the more heavily fertilized ponds is sixty per cent of what would be found on productive silt loam according to the results of Weir ('31). Although the amount of carbon varied considerably there is a definite relationship between the amount of fertilizer used and the amount of carbon. The quantity of nitrogen was almost directly in proportion to the amount of fertilizer used per week.

What relation these data bear to the fertility of the pond remains to be seen. Since none of the bottoms approached the 40:1 ratio of cottonseed meal it indicates that the greatest portion of the fertilizer is decomposed and used immediately. This decomposed portion either goes into solution or is utilized by the organisms and tied up in the animal cycle of the pond.

Another medium for converting the fertilizing materials to forms more available are the rooted aquatic plants. No doubt the submerged types have the ability to extract dissolved substances directly from the water, but the majority also remove mineral substances from lower layers of the soil and make them available, eventually, to other organisms by bringing them to the plant above the surface of the bottom.

Ponds which were not fertilized this year yielded an estimated production of from 3.86 tons per acre to 6.81 tons per acre depending upon the type of vegetation. This was on air dried samples. *Potamogeton americanus,* which is relatively thick stemmed, yielded 6.81 tons per acre, while *P. filiformis* yielded from 3.86 to 4.08 tons per acre in three ponds sampled. This compares favorably with hay crops which average about two tons per acre and with soy bean hay which averages three and one-half to four tons per acre in the same vicinity.

The importance of this amount of vegetation for its fertilizing value cannot be overestimated. Chemical analysis of these plants showed *P. americanus* to consist of 38.52 per cent carbon and 2.1 per cent nitrogen; *Ceratophyllum demersum* contained 42.38 per cent carbon and 1.9 per cent nitrogen. The ratio of carbon to nitrogen was 18.6:1 in the former and 22.8:1 in the latter. This compares favorably with green vegetables which have a ratio of 25:1.

Table 1—Chemical analysis of pond plants.

Plant	Tons per acre	Per cent carbon	Per cent nitrogen	Ratio C/N	Pounds N_2 per acre	Tons meal equiv.
Potamogeton americanus	6.81	38.52	2.08	18.56	282.2	2.02
Ceratophyllum demersum	—	42.38	1.86	22.78	—	—
P. filiformis	3.09-4.08	30.18	2.45	12.31	188-200	1.35-1.43

The analysis of *P. filiformis* from a pond fertilized heavily with

5:15:5 commercial fertilizer showed 30.2 per cent carbon and 2.45 per cent nitrogen. This gave a ratio of 12.3:1 which is low. Undoubtedly the use of so large an amount of inorganic nitrogen affected the makeup of the plant, as was reflected by the low carbon and high nitrogen content. Similar occurances have been noted in farm crops.

On the basis of the chemical analysis of these plants, the fertilizing value of one acre of submerged vegetation is equivalent to between 1.35 and two tons of good cotton seed meal. When one considers that the maximum amount of meal that was used in any of the ponds over the season was 1,100 pounds, he can readily see the tremendous amount of fertilizing value tied up such shape that it cannot be utilized until the next season. This can be reduced by the control of plants with sodium arsenite to inhibit excessive growth. When the vegetation is removed entirely from the ponds just so much fertilizing value is thrown away. In ponds treated with sodium arsenite at the end of the season to kill off the plant growth, decomposition sets in forming soluble compounds which are drained down the outlet and lost to the pond. Vegetation cut and stacked is not obnoxious to the pond and in those held dry until the early part of the next season one will readily note the returns by the myriads of crustacea working the shores and the vicinity of the piles. The removal of vegetation is a double drain upon the fertility of the pond since the primary crop in the form of fish will also be removed.

Vegetation in ponds, in addition to being a habitat for aquatic organisms and serving as protection for the fish from one another, has the function of converting otherwise inaccessible compounds into organic material. It therefore plays a definite part in the fertilization of the pond and compares favorably with land crops in this respect. On the other hand, an excessive growth tends to tie up fertilizing materials so that they are not available until the following season.

As a matter of fact, excessive growth of vegetation cuts down the amount of plankton to almost nothing even though the pond is being fertilized heavily. This has been shown time after time in the samples taken from our ponds. However, heavy fertilization sometimes result in such dense phytoplankton as to effectively limit the growth of leafy vegetation.

Summary

Literature has been cited to show that bacterial activity is of primary importance in the ecology of aquatic habitats; that organic substances are necessary to furnish the required energy in the form of carbohydrate materials for the synthesis of animal life in the pond, and that nitrogen, which may be derived from inorganic sources and may be first tied up in cell substance, is necessary for the utilization of the carbohydrates.

In fertilized ponds the organic matter from zooplankton and phyto-

plankton sources is insignificant as compared with that from bacteria. It was found that the dissolved residue from the filtrate of the Berkefeld filter was 202 mg/1 as compared with a dry residue of 43 mg/l in Wisconsin lakes.

The ratio of C/N in these pond bottoms was from 9.5:1 to 20:1, depending upon the amount of fertilizer used, as compared with 7.9:1 and 22.6:1 on a newly stripped pond bottom and in the surface soil of the same neighborhood. Good soil carries a ratio of 20:1.

Submerged plants in the ponds varied from 3.9 tons per acre to 6.8 tons depending upon the type of growth. Chemical analysis of the vegetation revealed that the fertilizing value of one acre is equivalent to between 1.35 and two tons of good cotton seed meal. The removal of vegetation from the ponds is the removal of the basic materials upon which the ecological cycle depends and which is limited by the amount of these materials added from outside sources.

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NOTES ON THE HABITS OF THE CRAYFISH, CAMBARUS RUSTICUS GIRARD, IN FISH PONDS IN OHIO

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Several species of crayfish occur in the ponds of the Ohio State fish farms, and, although many of them are detrimental because of the deep tunnels they make, one species, Cambarus rusticus Girard, is characterized by such burrowing habits as to make it comparatively harmless in this respect while certain other habits have results of considerable beneficial significance. These are, specifically, its habit of migrating onto the shoals of the ponds in the evening to feed upon the wastes which have accumulated there as a result of casting food to the fishes in that zone during the daytime, and also to stir into suspension the materials of the pond bottom, thus rendering the water turbid, and, indirectly in this manner, eliminating the vegetation from the pond.

According to Turner, this species is extending its range eastwards and has only recently entered Ohio from the west. The ponds of all of the State fish farms, including the one located at Chagrin Falls, in the northeastern section of the State, are now yielding considerable numbers of individuals of this species, and the entire State of Ohio may properly be included in any statement of its distribution.

In addition to their value in the fish ponds, these crayfish thrive in streams and lakes where they serve an important function as food for bass. The widespread use of soft crayfish by anglers as bait has led to the removal of quantities of them from fishing waters, an obvious drain on the available supply of bass food. Most of this drain could be prevented by the production of crayfish in ponds by dealers in live bait, and the following notes are presented with the purpose of providing basic information for this sort of enterprise.

The principal mating season occurs during the descending temperatures of latter September and October, when pairs may be seen on their sides or one atop the other on the pond bottoms. At this season the females all contain large and well developed ova which are nearly black in color. The number of eggs increases with the size of the female, as shown by the following table, and females too large for use as bait should be kept as brood stock.

Immediately following copulation the females burrow into the levees at the water line, the tunnels being therefore nearly horizontal and never deeper in this direction than two and one-half feet. In case of dense populations, the burrows may contain closely packed balls of

Length—Antennal Scale To Tip of Tail	No. of Eggs
46 m.m.	80
58	160
67	193
77	370
87	281
102	574

crayfish, one of which contained 67 individuals. Some old males are found in tunnels but no young ones, but old and young females form the majority of the crayfish found in tunnels in latter October.

When ponds are drained in late October the crayfish obtained are mostly young-of-the-year males. A random sample consisted of 124 young males and 21 females, and it is assumed that whilst the sexes occur in equal numbers the majority of the females are already in tunnels. Because of this habit, ponds stripped of all visible crayfish when drained in late October in Ohio produce another crop of crayfish the following year without adding further broodstock. It is probable also, that by draining a pond in early September before the crayfish pairing season, the crayfish can be effectively eliminated from a pond.

A small number of young females appear in berry after copulation in the fall, two being found in this condition on October 22nd out of hundreds examined at State Fish Farms No. 4 and No. 7. The majority of the females do not oviposit in the fall, however, but do so the following April and May, when just one year old. Crayfish wintered in spring-fed ponds appear in berry slightly earlier than those wintered in colder ponds. The spring-water ponds yielded females with eggs on April first, and the other ponds yielded their first females with eggs on April tenth.

In 1933 at State fish farm No. 11 crayfish were removed at intervals as the season progressed. Although length measurements were not made the increasing size was indicated by the decreasing number required to make a pound.

Date	Pounds	No. Per Pound	No. Crayfish
7-20	39	191	7,449
7-24	42	155	6,510
7-28	40½	151 2/2	6,142
8-7	97½	133 2/3	13,032
8-21	76	124 1/5	9,539
8-29	33	119 1/2	3,943

At State fish farm No. 2, pond 7, females were found with eggs attached on April tenth, with the eggs hatching on April 29th, and

with young ready to leave their mothers on May first. A sample of several thousands was removed from this pond on July first, and there were only eleven large individuals in the lot. Measurements show that normal variation in growth rate occurs. The crayfish were measured from tip of tail to tip of antennal scale.

L.mm.	*No.*	*L.mm.*	*No.*
0-24	0	80-84	0
25-29	9	85-89	1
30-34	37	90-94	3
35-39	70	95-99	3
40-44	67	100-104	3
45-49	44	105-109	1
50-54	9	110-114	0
55-59	0		

The crayfish growth rate varied with the temperature, the warmer ponds in the southern part of the State yielding bigger individuals than the ponds further north at any time during the season and at the season's end. State fish farm No. 2 is situated in the southwestern and warmest part of the State, No. 7 in the middle, No. 9 in the northwest, and No. 11 in the northeastern and coldest part of the State. Crayfish were removed from ponds at all four places, in early August, and the difference in size is indicated by the difference in number per pound.

S.F.F.No.	*Pond*	*Area*	*Pounds*	*No. Per Lb.*	*No. Crayfish*
2	4	.34	332	45 1/4	15,028
7	1	.50	500	72	36,000
9	1	.60	402	92	36,884
11	3		97	133 2/3	13,032

Crayfish serve best as bait when from two to three inches long. This length is attained earlier in the warm ponds than in the colder ones farther north and bait dealers who wish to propagate their own crayfish should select a site in the southern part of the State in order to obtain crayfish of the desired length early in the season when the demand is greatest.

No perfect system has been devised (to the author's knowledge) for making crayfish soft or for keeping them alive in that condition. The soft craw is one which has grown to the point of splitting open its hard shell and crawling out of it in a new one which has not yet hardened. The growth rate decreases with age so that the individual is soft more often when small than later on. Moulting does not occur in the winter time because growth then is at a standstill. The bait dealer's desire for a constant supply of "soft craws" can best be fulfilled by maintaining

quantities of crayfish in ponds where they can be fed to promote growth and selecting the peelers and soft crayfish as desired.

According to Turner (1926, p. 157) peelers and soft crayfish are preyed upon by hard individuals. This probably explains the tendency of peelers to seek the security offered by holes or cover. The provision of holes for peelers to crawl into (such as rows of cans along shore just below the surface of the water) would probably facilitate the removal of soft crayfish from a pond.

Many of the crayfish spend their days in shallow horizontal burrows under the edge of the turf at the pond margin, while many others remain in the deeper water during the daytime. The crayfish are most active in the early evening, and can be easily removed by seining after baiting onto the shoals with meat scraps just before dark. The effectiveness of this procedure may be illustrated by two instances. At State fish farm No. 9, using this method, 1,060 pounds of crayfish, numbering 120,188 individuals, were obtained, and when the ponds were drained they yielded only fifty-four pounds, 1,350 crayfish, additional. Also at State fish farm No. 2, 320 pounds of crayfish were removed with seines, and only twelve pounds more were obtained when the pond was drained immediately afterwards.

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Discussion

Mr. Langlois: I make no comment in this paper on the usefulness of this species of crayfish to use in propagating bass in Ohio; I have talked to this Society enough about that before. But I might perhaps mention the feeding system we use in Ohio for rearing bass, namely grinding up carp which we remove by seining from state owned lakes and hand feeding the bass on this carp. We do not want vegetation in our ponds; vegetation is the principal obstacle we have to overcome in successfully feeding our bass, and the introduction of this species of crayfish has proven the most effective device for controlling vegetation. We use sodium arsenate and copper sulphate, and we find certain disadvantages connected with the use of each of them. The crayfish eliminates vegetation by making the water roil, and of course as soon as the sunshine cannot penetrate the roily water the vegetation is eliminated, and when the ponds are drained in the fall they are just as bare on the bottom as this platform.

Mr. Kingsbury: When you put this crayfish in the pond in the spring of the year, does it have any effect on the production of Daphnia in the pond?

Mr. Langlois: The mere addition of crayfish to these ponds is not sufficient to produce the roil and eliminate the vegetation. At the time the crayfish are put in, men go into the ponds with scythes and manually remove as much of the vegetation as they can; they roil the water by their activities, and thereafter

S.F.F. No. 2, Pond 8. Area 1/3 acre. Yielded 38,617 crayfish, weighing 529 pounds, in 1935, in addition to bass crop.

S.F.F. No. 2, Pond 8. Crayfish migrating to channel and catchbox after fish have been removed.

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the crayfish keep it roily. It seems that the balance between vegetation and turbidity is a rather delicate one. When the vegetation is abundant it keeps down the turbidity, but once the water becomes turbid the vegetation cannot become re-established. But this roil does not come as a rule until after the fish have passed the Daphnia feeding stage.

MR. AITKEN: What is the nature of the bottom of these ponds that are roily —sandy, or of a clay or loamy type?

MR. LANGLOIS: The ponds that get roily in this way from crayfish all have clay in them. Straight sand and gravel ponds do not get roily in that way. We have deliberately put clay in some of the ponds on purpose to provide this material for roil.

EFFECTS OF CARBON DIOXIDE ON THE DEVELOPMENT OF TROUT EGGS

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U. S. Fisheries Experimental Station, Leetown, W. Va.

Ransom (1867) experimented with stickleback eggs to ascertain the effect of poisonous substances, including carbonic acid, on the contraction of the "yelk" in impregnated eggs. He showed that carbonic acid arrests development and may result in the production of abnormal forms which never reach the free-swimming stage. The injurious results were described by him but the limits of toxicity in parts per million were not defined in this early paper. Smith and Clowes (1924) observed that increasing CO_2 tension decreased the rate of division of certain marine eggs. They called attention to the remarkable penetrating power of CO_2 which they stated "seems to penetrate living tissues with far greater facility than any other known substance, including water." Hall (1925) made studies on the effects of oxygen and carbon dioxide on the development of whitefish and noted that the most sensitive stages in whitefish development seemed to be the first cleavages and early gastrulation. Her experiments centered about gradient reactions to acid and alkaline waters.

The writer knows of no studies on the effects of carbon dioxide on the eggs of trout. As early as 1885, Weigelt (1885) reported experiments with trout beyond the fry stages. He found that large trout showed immediate signs of distress when placed in seventy-five and 110 parts per million CO_2. The trout in seventy-five p.p.m. later became quiet. Winterstein (1908) determined that perch were asphyxiated at about 140-150 p.p.m. free CO_2. Reuss (1910) found that the respiration of rainbow trout became labored at thirty p.p.m., and that fifty, sixty-five and eighty-three p.p.m. induced erratic movements and at eighty-eight and 107 p.p.m. the trout turned over on their backs. Wells (1915) found thirty-six p.p.m. CO_2 without depleted oxygen fatal to fishes. He also made the interesting observation that fish spent much time at the surface "as is characteristic when the concentration of carbon dioxide is high." It has been noted several times that yearlings, or larger, rainbow trout at the Leetown Hatchery when brought inside and placed in troughs spend much time at the surface. This results in thickened dorsal fins and occasional specimens with the epidermis thickened on the back. Gutsell (1929) noted that thirty-nine p.p.m. of free CO_2 did not appear to harm trout in his experimental observations. Dr. E. B. Powers (1922, 1922a) has made observations on the physiology of the respiration in fishes and the effects of change in carbon dioxide tension, hydrogen-ion concentration, and alkaline re-

serve of the blood. His recent work on carbon dioxide tension (Powers, 1923, 1927, 1928, 1929, 1930, 1934) provides some explanations for losses of fish under conditions which would seem almost unexplainable.

Occasional determinations of the carbon dioxide content of the hatchery supply of the U. S. Fisheries Experimental Station, Leetown, W. Va., were made during 1932 and 1933 in the course of studies on the fish-carrying capacity of our troughs. As much as 25-30 parts per million free CO_2 were recorded, but during the fall, winter, and spring egg-taking and hatching period of 1934-35, determinations showed higher carbon dioxide contents than previously recorded. When the CO_2 experiments were first undertaken, as much as fifty-nine parts per million occurred in the supply as it entered the hatchery. This was before aeration. However, after passing through three milk pans with perforated bottoms at the head of the upper troughs, the amount was reduced to about forty-six parts per million. In spite of this high carbon dioxide content, the pH remained about neutral (7.1). This is accounted for by relatively high alkalinity of 264.5 p.p.m. and a total hardness of 509 p.p.m. This amount of hardness is rather unusual as hatchery supplies go, and is no doubt due to the location of the spring in a limestone region in which the surface and sub-surface soil is composed of a high percentage of calcium carbonate (marl). The high CO_2 at both the Leetown and Lewistown hatcheries is associated with ample oxygen content, which according to Wells (1913) increases the resistance of the fish to high carbon dioxide.

Rather late in 1934, after our brook trout had completed spawning, it occurred to the writer that the cause of our poor success with brook trout eggs during the first spawning season at this station might be the high carbon dioxide content. This idea developed as a result of an analysis made on the water supply of a nearby State hatchery at Lewistown, Maryland, in which all eggs in the hatchery were lost. This hatchery had been able previously to hatch eggs. The water supply of soft water (ten p.p.m. of methyl orange alkalinity) was piped 2,700 feet from a spring on a mountain side down a considerable slope to the hatchery. It originally had been allowed to flow into the hatchery in a six-inch pipe through the last 700 feet before it entered the head troughs. Due to a recent change, the six-inch line was used to bring creek water into the hatchery while the main line from the spring was reduced during the last 700 feet from a four to a two-inch pipe with disastrous results. An analysis of the direct supply showed fifty-one parts per million of free carbon dioxide and a pH of 5.4, which is decidedly acid as trout waters go. Experiments were then conducted to determine if enough of the gas could be removed by mechanical agitation to lower the carbon dioxide content and raise the hydrogen-ion concentration to a point where eggs or fish would survive.

The most efficient mechanical aerating device set up reduced the CO_2

content to about eight p.p.m. and raised the pH to 6.0. However, eggs and fish fared little better than before. When three to four-inch brook trout were placed in water of eight parts per million, they lived for eighteen to twenty-four hours instead of eight hours, the maximum length of time in direct spring water in the hatchery. However, brook trout from the same lot lived without visible suffering in the spring at its source where the CO_2 content was fifty-one p.p.m. and the pH 5.5. When the main pipe line to the hatchery was tapped 700 feet from the hatchery and the CO_2 reduced to eleven parts per million, brook trout fingerlings were still able to live. This suggested that some chemical element such as the metal lead, used in some joints of new pipe, might be the cause of the trouble. A complete chemical analysis of the water showed no trace of lead and no other toxic chemicals in injurious quantities, and when all free carbon dioxide was removed from the Lewistown Hatchery water supply continuously with caustic soda supplied by a constant flow siphon, it became possible to hatch a few eggs. Thus it appeared probable that the trouble lay in some mysterious manner with the high free carbon dioxide content. Determination of CO_2 tension by Powers' methods (1927, and subsequent papers) showed a marked difference in CO_2 tension in passage of the water from the head spring to the hatchery. Powers (1934) has shown that sudden changes in CO_2 tension have proved fatal to fishes.

These observations were made simultaneously at both Lewistown, Maryland, and Leetown, W. Va., where a large number of experimental lots were under observation. In some early experiments at Leetown, a lot of 989 green rainbow eggs from our own fall-spawning rainbows and 906 green brook trout eggs purchased from a private hatchery were placed in an upper hatchery trough receiving the direct hatchery supply without aeration. This water averages 40.78 parts per million of free carbon dioxide which was fairly constant throughout the experimental period. Similarly, two lots of eggs of both kinds of trout were placed in a lower hatchery trough in which the free carbon dioxide was raised to an average of 78.45 parts per million by bubbling carbon dioxide (under constant pressure) into the water at the head of the trough. In the rainbow trout control lot in the upper trough at 40.78 p.p.m. free carbon dioxide, there was a hatch of 68.45 per cent of normally formed fry accompanied by 1.02 per cent of deformities. In the experimental lot of rainbow eggs in 78.45 p.p.m. free CO_2 there was a hatch of only 47.61 per cent normal fry. This was accompanied by 6.90 per cent of deformities.

The amount of free carbon dioxide in the experimental trough was only about eighteen p.p.m. higher than the hatchery water supply as it entered the top pans of the deaerators at the head of all troughs. In past seasons the carbon dioxide content had not been sufficiently high to cause many deformities in rainbow fry, however, during the current season it was estimated (not quantitative) that there was ninety per

cent more deformed rainbow fry in 1935 than in 1934. Two reasons were given for the probably higher CO_2 content of the water supply (1) the occurance of a 2.2-inch rain following a week of rain ending November 28, 1934; (2) the covering up of the head spring hole, source of the hatchery supply, which was formerly exposed and which supported a dense growth of algae, chara, and other rooted plants which utilized CO_2 in photosynthesis. The 1935 results with brook trout eggs were poor, worse than in 1934, and accompanied by more deformities and blue sac.

Further evidence is at hand supporting the results obtained in the control lots. In a lower trough (trough forty) averaging 33.48 p.p.m. free CO_2, a hatch of 66.14 per cent of normal fry in the rainbow and 5.24 per cent in the brook lots was recorded. This was accompanied by 5.21 per cent of deformities in the rainbow and 25 per cent in the brooks. Brook trout hatched in water in which the CO_2 was removed by mechanical agitation gave somewhat lower per cents of normal fry hatched than in the two controls, but considerably fewer deformed fish.

While the green rainbow eggs used in the experiments were taken from fish at the station, it was necessary to secure green brook trout eggs from a commercial hatchery about 200 miles distant and transport them to the hatchery at Leetown. Upon their arrival at Leetown heavy losses occurred. These losses may have been due to the rough transportation, the change from very soft to hard water, or to the quality of the eggs which experienced fish culturists state is usually rather poor at the end of the spawn-taking period. Nevertheless the eggs were carefully taken care of and CO_2 samples and records were kept in the same manner as with the rainbow eggs. Although the results are very poor, they are uniform and in several ways are indicative of a cause of high brook trout egg and fry losses at the Leetown station. In the control lot of brook trout eggs (40.78 p.p.m. of free carbon dioxide), there was a hatch of 4.08 per cent normal fry accompanied by 19.57 per cent of deformed fry. In contrast, only 0.136 per cent of normal fry in 78.45 p.p.m. of free CO_2 was obtained. This was accompanied by 83.33 per cent of deformities. These results clearly indicated that the above amount of carbon dioxide interferes with the normal development of embryo rainbow and brook trout.

These first experiments on this important subject were performed at the end of the regular trout spawning season. However, it was still possible to secure eggs of spring spawning rainbow trout from the U. S. Fisheries Experimental Station at Pittsford, Vermont, and eggs from our own black spotted trout. Eggs from both species were taken on the same date, April 10. Black spotted eggs were again taken on April 25, 1935. The rainbow eggs were shipped green immediately after being taken and were received in good condition on the morning of April 12. These eggs, with the exception of lot 187 in CO_2 free water (CO_2 removed with caustic soda), started hatching in 26 days

and ended hatching by the 31st day. The exception, lot 187 began hatching and ended hatching two days earlier than the other rainbow lots. Black spotted trout eggs started hatching after 23 days and ended hatching on the 26th day. The result of the experiments are summarized in Table 1.

Samples for carbon dioxide determination were collected over the egg trays or between them with a 100 C. C. bulb pipette. The egg trays were placed near the foot of the troughs away from the aerating devices or points where carbon dioxide from storage tanks was introduced. In troughs fifty-six, fifty-eight and sixty where CO_2 was introduced, the gas was led from a pressure regulator through a needle valve to the nipple of which was attached a small bore rubber tube. The end of the tube was weighted and placed under a battery jar inverted in the water at the head end of three lower troughs (56, 58, 60). The water from the upper troughs (55, 57, 59) was siphoned by a short length of hose to a point about the middle of the inverted battery jar. The weighted ends of the tubes from the gas tanks had their outlets at the points where the water emerged from the siphons. This insured a prompt mixture of gas and water and reduced the waste of CO_2 gas which displaced nearly all water in the jars. It was necessary to tie the jars down with a harness to keep them from raising out of the water and moving about. The different types of deaerators were located at the upper ends of the upper troughs (55, 57, 59, 53) where the water flowed from the spigots. Details regarding the construction of the deaerators are omitted. None of them were highly successful, but we were limited to a working space of about two feet in which to get aeration. Aerating nozzles and increased pressure could not be utilized to break the water because there was not sufficient difference in elevation between the head spring and the upper troughs.

Table 1 shows the number of eggs started in each experiment, the per cent of eyed eggs, the per cent of deformed fry, and the important end result, or per cent of normal fry. In the summary which was given for the early experiments, per cent of deformed fry included only those with twisted spines, etc., which were visibly deformed. In Table 1, however, the per cent of deformed fry was calculated by subtracting the post-eyed egg and fry losses from the number of eyed eggs. This was done because it was noted that those embryos which reached the eyed stage and did not hatch were nearly all deformed in some way. The actually deformed fry were counted but the number is not shown. From an examination of the table, it is noted that the losses after the eggs are eyed are considerable, particularly where there is a considerable quantity of carbon dioxide present as in troughs 56, 58, 60. The number of actually deformed fry was not determined in all lots, but in the rainbow lots a decidedly higher percentage of deformed fry occurred in the high CO_2 troughs than in the control lots in 57, 53, and 55. It was therefore demonstrated as in the earlier experiments that an ex-

TABLE 1. SUMMARY OF LATER EXPERIMENTS ON EFFECTS OF DIFFERENT CONCENTRATIONS OF CARBON DIOXIDE ON SURVIVAL OF TROUT EGGS

						Rainbow trout of April 10			—Cut throat of April 10—			Cut throat trout of April 25
Trough No.	Conditions	Average pH.	CO_2 level parts per million	Lot No.	No. eggs	Per cent eyed	Per cent deformed	Per cent normal fry	Per cent eyed	Per cent deformed	Per cent normal fry	Per cent eyed
57	Caustic Soda	7.7	0.0	187	5,284	83.42	1.17	73.01	......	......	......	......
				179	5,113	......	......	......	12.69	6.17	9.82	......
				194	436	......	......	......	......	......	......	13.76
53	Shelf Deaerator	7.2	27.7	183	4,427	87.24	1.64	79.92	......	......	......	......
				176	2,545	......	......	......	8.80	25.00	3.06	......
				198	274	......	......	......	......	......	......	16.42
59	6-pan Deaerator	7.3	28.7	189	4,146	87.48	......	83.04	......	......	......	......
				181	1,459	......	......	......	23.17	10.26	19.19	......
				192	562	......	......	......	......	......	......	8.01
55	3-pan Deaerator	7.1	35.8	185	4,312	90.75	1.87	80.87	......	......	......	......
				177	4,159	......	......	......	24.40	21.08	11.25	......
				195	340	......	......	......	......	......	......	12.06
33	No Deaerator	7.1	43.1	184	5,485	82.66	......	78.80	......	......	......	......
				199	405	......	......	......	......	......	......	2.47
50	CO_2 re-introduced	7.1	44.4	188	4,768	90.48	4.16	73.49	......	......	......	......
				180	2,010	......	......	......	10.65	21.98	7.06	......
				196	408	......	......	......	......	......	......	16.91
60	CO_2 tank	7.0	57.1	190	5,865	77.14	......	67.89	......	......	......	......
				182	3,084	......	......	......	3.11	......	0.81	......
				191	499	......	......	......	......	......	......	8.42
				193	443	......	......	......	......	......	......	3.39
56	CO_2 tank	6.9	78.4	186	4,427	77.43	10.46	43.62	......	......	......	......
				178	2,072	......	......	......	0.00	......	......	......
				197	300	......	......	......	......	......	......	3.33

Black Spotted Trout and Cut Throat Trout are the same species, Cut Throat Trout being used in this table for brevity.

cessive amount of carbon dioxide increased the number of deformed fish. Results with cut-throat trout eggs were erratic as to percentage eyed and hatched, but it was evident that those eggs incubated in troughs 56 and 60 with the highest carbon dioxide concentrations were decidedly affected by 78.4 and 57.1 parts per million of free carbon dioxide, respectively.

When about half of the eggs (lot 194) from a single pair of cut-throat trout were placed in trough fifty-seven, where all CO_2 was removed, and the remaining half (lot 196) in trough fifty-eight, where the amount of CO_2 was raised from 0.0 to 44.4 parts per million, little difference was noted in the per cent eyed, but those in trough fifty-eight gave the highest percentage of eyed eggs. When half of the eggs (lot 191) from another female were placed in 57.1 parts per million CO_2 and the remaining half (lot 192) in water averaging 28.7 p.p.m., lot 191 gave slightly the largest number of eyed eggs. Again the quantities of CO_2 appeared not to influence results. The observations with these lots are exceptions to the general results.

Egg lots 195, 197, 198 from the same female were placed in water having 35.8, 78.4 and 27.7 parts per million of carbon dioxide, respectively. The expected results were obtained, lot 197 having the lowest percentage of eyed eggs (3.33); lot 195 was next with 12.06 per cent; and lot 198 had 16.42 per cent.

Half of the eggs (lot 193) from the same fish were placed in water averaging 57.1 p.p.m. CO_2 while the remaining half (lot 199) were placed in water with 43.1 p.p.m. The results were about the same, both being low, about three per cent eyed, indicating that both concentrations were excessive or that the quality of the eggs were inferior.

The results of these later experiments agree with the earlier results with two exceptions mentioned above. Most of the experiments were conducted with bulk takes of eggs containing the spawn from a number of females. The desirability of attacking the problem from a different angle with eggs from the same fish has been illustrated by the results with lots 194, 196, 191, 192, 195, 197, 198, 193 and 199.

The need of a better understanding of carbon dioxide relations is emphasized by the following incident which is probably one of many that remains partly or wholly unexplained. Recently, 15,000 rainbow fingerlings were transferred from the Leetown Hatchery to hatchery troughs at Ogletown, Pa., where 5,500 of them died within two days; although handled carefully by experienced men. The cause of the loss was followed up before the death of all fish. It was determined first that the fish did not die from gill disease or some other disease epidemic. Then chemical analysis was made of the water into which the fish had been placed at Ogletown. Here it was found that our fish had been transferred from a water of pH 7.1, 285 parts per million alkalinity, CO_2 content of 35.8 p.p.m., and CO_2 tension of about .00916 atmosphere to water of pH 5.4 methyl orange alkalinity of 6.9 p.p.m.

CO_2 content of thirty-eight and CO_2 tension of about .04952 atmosphere — a decided change in carbon dioxide tension and other water conditions which probably made the resumption of normal respiratory activities very difficult and impossible in more than one-third of them. There are probably many examples of fatal plantings or transfers from the same or a similar cause.

The writer wishes to thank Dr. H. S. Davis, in charge of Aquicultural investigations, for suggestions during the course of the work and preparation of this paper. Mr. A. M. Powell, Superintendent of the State Hatchery at Lewistown, Maryland cooperated in the work and carried out the fish planting experiments described for his water supply.

Summary

The presence of amounts of free carbon dioxide in excess of thirty-five parts per million in the water supply of two hatcheries was studied in its relation to the incubation and development of rainbow, black-spotted, and brook trout eggs. In one of these hatcheries (Lewistown, Maryland) the method of bringing the water supply with an open flume to the troughs had been changed to closed pipes to the point where the water entered the troughs. This change made it impossible to hatch eggs with the spring water supply. In the other hatchery (Leetown, W. Va.) reasonably good success was had with rainbow eggs in spite of the high CO_2, but poor results were obtained with brook, brown, and black spotted trout eggs. The greater prevalence of deformed rainbow fry over the preceding spawning season called attention to the higher CO_2 content which followed the covering of the main spring which supplies the hatchery. Experiments were performed in which the carbon dioxide content of certain troughs was increased artifically with CO_2 under constant pressure from commercial tanks. Control experiments were conducted in water aerated to different degrees to remove the CO_2 by mechanical means, and also in water in which all free CO_2 was removed with caustic soda. These studies showed that concentrations of carbon dioxide between fifty-five and 78.5 parts per million increased decidedly the post-eyed egg losses and the number of deformed fish. When caustic soda was added to the Lewistown soft and acid water, it became possible to hatch a few trout eggs where formerly all eggs were dead in a few days.

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Discussion

Mr. Deuel: May I ask Mr. Surber what methods he used to determine his carbon dioxide?

Mr. Eugene Surber: Seylor's method, with a 100 c.c. Nessler jar was used for free carbon dioxide determination, while Power's methods were followed in the determination of carbon dioxide tension.

Dr. Hubbs: I would like to ask what was the type of abnormality.

Mr. Eugene Surber: I have photographs here which I should be glad to show you. The type of deformity with the rainbow trout was that of a curved spinal cord instead of the normal straight spinal cord. With the brook trout it became very extreme. The photograph I have here is not very good, but you can see that the spinal cord of the brook trout in some cases is twisted one and a half times; it is like the horns of a Rocky Mountain sheep. I shall be glad to pass these photographs around.

Dr. Hubbs: I am wondering in asking this question what bearing this work might have on the causes of abnormalities in fish observed in polluted waters. Undoubtedly some of these abnormalities are due to disease, but I am wondering if some of them are not due to the conditions of the water, possibly the carbon dioxide tension being increased especially on the bottom where sludge will accumulate and increase the carbon dioxide in the bottommost layer of the water. We can sometimes quite easily distinguish collections of fish from polluted and unpolluted water by the percentage and character of abnormalities in the fish.

Mr. Deuel: Did you notice any indication of gas bubble disease in your hatchery?

Mr. Eugene Surber: Our trouble is due to blue sac, the yolk membrane being filled with serous fluid. On second thought, we do have gas bubble disease which causes the eyes of our fish, if held under certain conditions, to protrude from their sockets.

FACT VS. THEORY

A. H. Dinsmore

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It is said that Professor Agassiz once questioned an assertion made by Senator Frye as to the size of brook trout he had caught and stated that the maximum growth of that fish was five pounds. When, a few days later, from his camp in the Rangley Lake region, the Senator sent him a fish considerably exceeding five pounds in weight the Professor immediately showed his caliber by wiring, "The theory of a lifetime knocked in the head by a fact."

Because the correctness of some statements made by the writer, entirely from memory after a lapse of almost a quarter century, have been questioned the records in the case have been looked up. The statements referred to were made at the Montreal meeting of the Society last year and in all essentials are correctly reported on page 362 of the Transactions for the year 1934. They have to do with an artificially produced run of sockeye or blue black salmon, *Oncorhynchus nerka.*

Because these records refute absolutely, the popular theory that the sockeye can only reproduce by reaching the waters of glacial fed lakes; because they seem to prove with equal certainty that the homing instinct is more powerful than the influence of temperature in leading the returning fish to their spawning grounds; and because it should give some pause to those who so vociferously deride the planting of unfed fry, a brief draft from these records seems justified.

In August a small number of sockeye salmon were taken directly from the traps at the mouth of the Fraser River and held in a fresh water pool just above tide water, near Blaine, Washington. The fish matured their eggs in early October, just as naturally as they would had they made their way to some glacial fed lake in the Cascade Mountains. A total of 64,000 eggs were taken. They were transferred green to the hatchery of the Bureau of Fisheries at Birdsview, Washington. From these eggs, 46,000 fry were produced and planted, unfed, in Grandy Lake, near by, in the spring of 1909. This would seem to prove beyond the possibility of doubt that it is unnecessary for the sockeye to reach glacial water to reproduce successfully.

As Grandy Lake is remembered, it has an area of 100 acres, more or less, and lies in the foothills, slightly above the Skagit Valley. It is the source of Grandy Creek, normally a small brook, entering the Skagit River a few miles below the Lake. The writer operated this stream seven seasons for the collection of the eggs of humpback, silver, and Chinook salmon and steelhead trout. During all these years he never saw a sockeye salmon there, though the employees of the station told him that occasionally a stray fish did come in. Ex-Commissioner O'Malley, who established the station and operated it several

years before the writer succeeded him, states positively that there never was a run of sockeyes to this stream during his superintendency.

It seems an undisputed fact, therefore, that within the knowledge of the white man, until the plant referred to was made, practically all sockeye salmon entering the Skagit went to the Baker River, some eight miles above the mouth of Grandy Creek. Grandy Lake was convenient and seemed a favorable place for planting these fry but there was little thought that a distinct run of salmon would result. The writer left the station in January, 1912, and is indebted to Mr. Joe Kimmerich, the present Superintendent of the station, for the record of the return run. Mr. Kimmerich writes:

> "The records * * * * show that between September 1 and October 3, 1912, 222,000 blueback salmon eggs were collected at Birdsview and this collection is no doubt the result from the 64,000 fry planted in Grandy Lake in the Spring of 1909. I cannot find any record of what disposition was made of the fry or fingerlings resulting from the 222,000 eggs collected. I am, however, able to find that on September 27 and 28, 1916, a total of 24,500 blueback salmon eggs were collected at Birdsview, which I presume was the result from the 222,000 eggs collected in the fall of 1912."

Note the four-year cycle involved in these salmon runs. Fish from the eggs collected at Blaine in 1908 returned to the waters in which the resulting fry were planted in the summer or autumn of 1912. There seems to have been no further run to the creek until the fish resulting from the collections of 1912 returned in the summer or autumn of 1916. Can it be doubted that the mature fish in each case sought, instinctively, the stream in which they had started their growth? In other words, that they had a true homing instinct for the stream of their origin, even though a more favorable stream was near-by?

Now let us consider the remarkable and seemingly unquestionable success of this plant of unfed fry in waters teeming with native trout. It must be conceded that surprisingly large number of the fry lived, grew, and passed out to sea when enough of them succeeded in fighting their way past all the fishing gear of Puget Sound and the lower Skagit River to reach the home stream and yield 222,000 eggs. It is regrettable that no record can be found of the disposition of the fish from these eggs—where they were planted and whether as fry or fingerlings—so that some conclusion may be reached as to why the return from this second distribution was as much less than from the distribution of 1909. That they did come back a second time, however, seems certain.

Summary

(1) The sockeye will mature its eggs as successfully at tide water as it will in the glacial fed lakes which it customarily seeks at the spawning season.

(2) The sockeye salmon returned instinctively to the stream in which it was planted even though this was not a natural spawning stream for the species and in spite of the fact that it entered the main salmon river in close proximity to the mouth of the favorite spawning stream of the region.

(3) A very high survival of salmon seems to have been secured when unfed fry were planted in a small lake not much above sea level.

ANALYSIS OF THE GAME-FISH CATCH IN A MICHIGAN LAKE

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A paper by G. H. Clark given at the Fisheries meeting in Montreal last year, and the discussion which followed, indicated not only that there is a real need for measuring and interpreting the angler's catch, but also that past attempts in this direction have been unsatisfactory. While that discussion was in progress in Montreal, crews of specially selected C.C.C. men were patrolling the shores of several Michigan lakes, to contact the fishermen as they reached the shore, and to obtain from them full data as to their day's fishing. The aim of the work was to secure as complete a record as possible of all fishing carried on throughout the year in these lakes. This project thus differed from the general Michigan creel census, which since 1927 has been attempting to obtain, by the method of representative sampling only, an appreciation of the trend of fishing throughout the state.

The purpose of this paper is to indicate the method used in taking a complete creel census on a lake, and to show what sort of information, of value or interest to the Department of Conservation and to anglers, can be obtained by such a census. These points are illustrated by the discussion of the census taken on one of the several lakes where this work has been conducted, and is being continued.

Fife Lake Creel Census

Results of the creel census on this lake are available for a full year of fishing (December 21, 1933 to December 20, 1934). This lake is located in the upper part of the Lower Peninsula of Michigan, in Grand Traverse and Kalkaska counties, approximately 20 miles southeast of Traverse City. Since it is on a national highway (U. S. 27), the lake is readily accessible at all times. It has an area of 820 acres within the meander line, reduced by low water at the time of the census to about 800 acres. Fife Lake has a considerable amount of shoal area and a moderate development of vegetation, and appears to be moderately rich in food. If it were possible to select an average Michigan lake, Fife Lake might approach it in most respects.

The creel census was taken by the Fife Lake C.C.C. Camp under the supervision of Superintendent A. L. Ferris and Crew Foreman Erwin Moody. The Camp Superintendent, a technically trained man, was interested in the project, and was sufficiently familiar with his enrollees to place on the census-crew men best suited for the work. Foreman Moody had previously been engaged in fisheries work for the Department of Conservation. This personnel assured the reliability of the data.

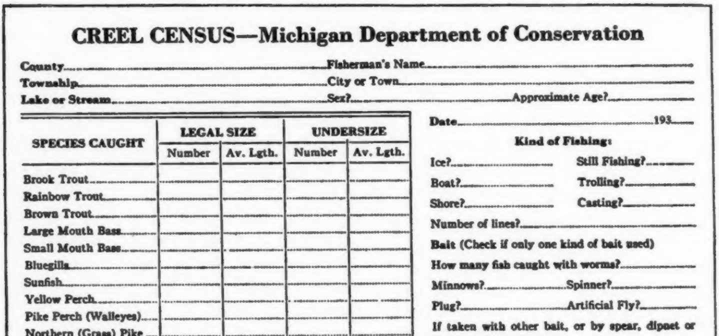
Method of Taking the Census

The men were equipped with special blanks for recording the data and suitable equipment for measuring the fish. In winter they were further equipped with portable headquarters,—a "shanty" which was kept in the vicinity of the most heavily fished area of the lake. In summer and fall the men patrolled the shore, each man being responsible for contacting the fishermen who reached his allotted section of the shore. The data were obtained only when the fishermen had concluded the day's fishing.

The census was taken every day from daylight to dark, except during the closed season in spring (April 30-June 25), when there was obviously no need for taking a census.

Each day the men prepared a list of the number of fishermen seen and the number actually contacted. Since the lake was relatively round and since the crew was of ample size (numbering up to seven men), it is assumed that all of the fishermen were seen. In the fall and winter all those who were seen were also contacted; in the summer 149 records were missed, for anglers seen but not contacted. The 35 blanks that were incompletely filled out or lost were added to these 149 records to give a total of 184 fishermen-days for which full records were not available.

The time of fishing was recorded to the nearest quarter hour; the length of the fish may be considered correct to the nearest half inch.


CREEL CENSUS—Michigan Department of Conservation

County................ Fisherman's Name................
Township................ City or Town................
Lake or Stream................ Sex?................ Approximate Age?................

SPECIES CAUGHT	LEGAL SIZE		UNDERSIZE	
	Number	Av. Lgth.	Number	Av. Lgth.
Brook Trout				
Rainbow Trout				
Brown Trout				
Large Mouth Bass				
Small Mouth Bass				
Bluegills				
Sunfish				
Yellow Perch				
Pike Perch (Walleyes)				
Northern (Grass) Pike				

(Enter other kinds taken on blank spaces above)

Date................193....

Kind of Fishing:

Ice?................ Still Fishing?................
Boat?................ Trolling?................
Shore?................ Casting?................
Number of lines?................
Bait (Check if only one kind of bait used)
How many fish caught with worms?................
Minnows?................ Spinner?................
Plug?................ Artificial Fly?................
If taken with other bait, or by spear, dipnet or other means, state how................
Weather: Clear?................ Cold?................
(Check) Cloudy?................ Mild?................
Rain?................ Warm?................

TIME FISHED ....HRS. A.M. P.M. 12 1 2 3 4 5 6 7 8 9 10 11 12

Draw line through hours fished; double line when fishing was best; figure to quarter hours.
Make separate report for every person fishing. Make out report whether fish are caught or not.

Fig. 1.—Blank used for recording the creel census data. Actual size 4 x 6 inches. These perforated sheets are made up in books of 100.

Data Obtained

Of the two forms of blanks employed, the one used in the early period of the survey differed from the one shown as Figure 1 primarily in that it lacked the address and approximate age of the fisherman. The form was prepared for use in the general creel census on lakes and streams, as well as for the intensive C.C.C. survey.

The information obtained for each day's fishing includes the name, address, sex, and approximate age of the fisherman; the kind, number, and size of fish caught; the date; the method of fishing; the bait used; the general weather conditions; the hours of the day fished, and the total hours fished; also the time of day when fishing was considered best.

The number, kind, and size of fish were checked by the census-takers and all information was recorded by them. It has been learned that the average angler finds the blank too detailed and too complicated, but that he is quite willing to furnish the desired information.

Summer Fishing

All fishing from the opening date of June 25th to September 30th inclusive has been considered as summer fishing. The extensive information obtained for this period, mostly indicated in detail in the tables and graphs, may be summarized as follows:

Number of fishermen, lines per fisherman, and fishermen taking no fish (see Table 1).—Census returns were obtained for 2,399 fisherman-days, 1,835 for men, 564 for women. A daily average of 24.5 persons fished the lake for the 98 day period; during the height of the fishing season the number of fishermen averaged about 37 daily. Although 2 lines per fishermen are legally permitted, 93 per cent of the reports indicated the use of only 1 line (an example of the sort of fact-finding that should interest legislators).

TABLE 1. NUMBER OF FISHERMEN, LINES PER FISHERMAN, AND FISHERMEN TAKING NO FISH. FIFE LAKE, SUMMER AND FALL OF 1934. EACH FISHERMAN IS LISTED SEPARATELY FOR EACH DAY FISHED

Date	—Number of fishermen— male	female	total	Ave. per day	Ave. lines per person	—Fishermen taking no fish— male	female	total	%
June 25-30	103	18	121	20	1.2	22	4	26	21.5
July 1-7	139	23	162	23	1.05	39	7	46	28.4
July 8-14	168	56	224	32	1.0	59	15	74	33.0
July 15-21	164	25	189	24.1	1.04	47	4	51	27.0
July 22-28	191	50	241	34.4	1.08	29	10	39	16.2
July 29-Aug 4	215	49	264	37.8	1.05	71	8	79	29.9
Aug 5-11	204	54	258	37	1.09	54	6	60	23.2
Aug. 12-18	180	79	259	37	1.09	32	13	45	17.4
Aug. 19-25	82	36	118	17	1.1	22	9	31	26.2
Aug. 26-Sept. 1	136	66	202	29	1.06	40	17	57	28.2
Sept. 2-8	87	30	117	16.7	1.06	26	6	32	27.3
Sept. 9-15	83	34	117	16.7	1.05	16	8	24	20.5
Sept. 16-22	45	24	69	9.9	1.04	5	2	7	10.1
Sept. 23-29	25	17	42	6	1.1	4	3	7	16.7
Sept. 30	13	3	16	16	1.0	0	0	0	0.0
Totals	1,835	564	2,399	24.48	1.07	466	112	578	24.1
October	130	60	190	6.1	1.22	22	6	28	14.7
November	6	2	8	.27	1.25	3	1	4	50.0
Totals for Oct. & Nov.	136	62	198	3.24	1.22	25	7	32	16.2

A total of 578 fishermen, 24.1 per cent of all those fishing (each day's fishing considered separately), caught no legal-sized fish; 466 of these were men, 112 were women. The percentage taking no fish varied from about 10 per cent to 33 per cent. Of all the reports 23.5 per cent were for women; of those indicating no fish caught 19.4 per cent were for women. Proportionately fewer women than men took no fish. There appears to be very little correlation between the number of persons fishing any week and the number catching no fish at that time.

Legal limit catches of bass or pan fish (5 bass, 25 pan fish), or over-limit catches, were indicated in less than 2 per cent of the reports. Only 10 limit catches of pan fish and only 25 limit catches of bass (mostly of smallmouth bass) were made. All limit catches except one were taken on natural bait. No limit catches of five northern pike or of five walleyes were made.

Number of fish, catch per hour, fish per fisherman, and average size of all fish (see Table 2).—The 2,399 fisherman-days yielded a total of 10,656 fish having an average length of 8.33 inches, caught at the rate of 1.72 per hour. The fishermen averaged approximately 4.5 fish each per day's fishing; Fife Lake produced, on the average, more than 100 fish per day for the 98-day period.

The per-hour catch as well as the total numbers of fish taken, varied from week to week. It was poorest for the week when most people fished (July 29th to August 4). Since there was some correlation between the catch per hour and the catch per fisherman, the average fisherman tended to fish for a more or less uniform average time without regard to his luck (also shown by Table 4).

TABLE 2. NUMBER OF FISH, FISH PER HOUR, FISH PER FISHERMAN, AND AVERAGE SIZE OF ALL FISH. FIFE LAKE, SUMMER AND FALL OF 1934

Date	No. of fish taken	Fish per hour	Fish per angler	Average size of fish (in.)
June 25-30	629	2.0	5.2	8.95
July 1-7	847	2.25	5.2	8.7
July 8-14	896	1.66	4.0	8.4
July 15-21	980	2.03	5.2	8.7
July 22-28	1,302	1.95	5.4	8.3
July 29-Aug. 4	918	1.24	3.5	8.4
Aug. 5-11	1,143	1.77	4.5	8.1
Aug. 12-18	1,083	1.7	4.2	7.85
Aug. 19-25	488	1.78	4.1	7.8
Aug. 26-Sept. 1	683	1.44	3.4	8.3
Sept. 2-8	370	1.29	3.2	8.0
Sept. 9-15	535	1.56	4.6	7.9
Sept. 16-22	464	1.9	6.7	8.2
Sept. 23-29	208	1.81	4.5	8.5
Sept. 30	110	2.0	6.9	8.8
Total or Average	10,656	1.72	4.44	8.33
October	1,275	2.46	6.7	8.4
November	31	1.8	3.9	7.7
Total or Average for October and November	1,306	2.43	6.6	8.0

Analysis of the catch by species (see Table 3 and Fig. 2).—The 12 or 13 species taken, were, in the order of abundance in the catch: perch (*Perca flavescens*), rockbass (*Ambloplites rupestris*), bluegill

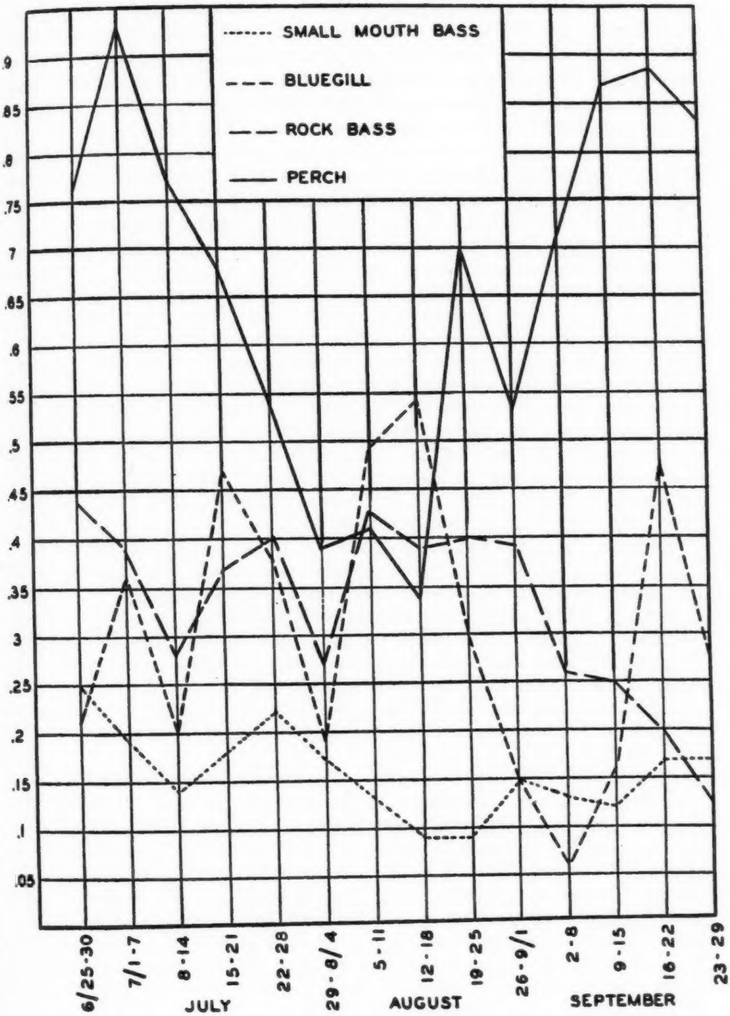


Fig. 2.—Fish per hour calculated to the nearest .01 hour for the species indicated above on a weekly basis. Fife Lake, summer of 1934.

(*Helioperca macrochira*), pumpkinseed (*Eupomotis gibbosus*), smallmouth bass (*Micropterus dolomieu*), bullhead (*Ameiurus nebulosus* and *natalis*), largemouth bass (*Aplites salmoides*), walleyed-pike or pike-perch (*Stizostedion vitreum*), northern pike (*Esox lucius*), black crappie (*Pomoxis sparoides*), sucker (*Catostomus commersonnii*), and shiner (probably *Notemigonus crysoleucas*). The average size for any one species remained relatively constant from week to week as the season progressed. The per-hour catch of each species fluctuated from week to week but the weekly fluctuations in the per-hour catch of any one species was not accompanied by a similar fluctuation in the per-hour catch of the other species. The four largest game fish, largemouth bass, smallmouth bass, northern pike and walleye, represented 12.6 per cent of the entire catch. The catch of smallmouth bass totaled 992 fish, of an average length of 12.25 inches. They represented 9.31 per cent of the total catch and were taken at the rate of 1 fish per 6 hours of all fishing. The per-hour catch was best during the first week of the season, possibly because spawning had recently been completed and the males were feeding heavily. The total large mouth bass catch was 294 fish, of an average length of 13.5 inches. They represented 2.76 per cent of the total catch and were taken at the rate of 1 fish per 25 hours of fishing. Smallmouth bass outnumbered the largemouths almost 10 to 3. It therefore appears that the lake might best be classed as a smallmouth bass lake.

The total bluegill catch was 1,970 fish of an average length of about 7.2 inches. The bluegills represented almost one-fifth of the total catch and were taken at the rate of approximately one fish per three hours of fishing. They were biting best in mid-summer and for several weeks during the height of the tourist season they ranked first in the catch. A total of 1,016 pumpkinseeds was taken. These had an average length of less than 7 inches, and represented 9.5 per cent of the total catch. The catch was decidedly inferior to the bluegill catch in number and in catch per hour; and the sunfish averaged somewhat smaller than the bluegills.

A total of 2,129 rock bass with an average length of almost 8 inches was caught. They represented 20 per cent of the total catch and were caught at the rate of 1 fish per 3 hours of fishing. Over a third (35.2 per cent) of the fish caught were perch. They had an average length of about 7.5 inches. The catch, in terms of fish per hour, dropped decidedly during mid-summer (Fig. 2). Most of the few walleyes (pike-perch) caught were taken during the first four weeks; few were taken after mid-July. On the average only one northern pike was taken from the lake every two days. A total of 303 bullheads were taken. They had an average length of 10.5 inches. The catch included 15 black crappies, 9 suckers and 4 shiners.

Total hours fished and average hours fished (see Table 4 and Fig. 3).—The fishermen fished for a total of 6,187.75 hours; 38 per cent of the fishing was in the morning, 62 per cent in the afternoon and eve-

ning. The daily fluctuation between morning and afternoon fishing was pronounced. Weather apparently was the chief factor responsible for this fluctuation. The average fishing day, 2.6 hours, varied relatively little from week to week. Obviously fishing on this lake did not occupy the major portion of the fisherman's time.

There were two daily peaks in fishing intensity (Fig. 3), one from 8:00 to 11:00 A. M., the other late in the afternoon. Over 10 per cent of all fishing was between 6 and 7 P. M. Fishing was best, how-

TABLE 3. ANALYSIS OF THE CATCH. FIFE LAKE, SUMMER AND FALL OF 1934*

Date	Smallmouth Bass No. taken	Smallmouth Bass Ave. size	Smallmouth Bass Per hr.	Largemouth Bass No. taken	Largemouth Bass Ave. size	Largemouth Bass Per hr.	Bluegill No. taken	Bluegill Ave. size	Bluegill Per hr.	Sunfish No. taken	Sunfish Ave. size	Sunfish Per hr.
June 25-30	80	12.3	.25	37	13.2	.12	67	7.1	.21	37	7.1	.12
July 1-7	73	12.0	.19	37	13.5	.10	136	7.2	.36	40	7.2	.11
July 8-14	76	12.2	.14	14	15.3	.03	110	7.0	.20	62	6.7	.11
July 15-21	86	12.1	.18	32	15.1	.07	231	7.5	.47	76	6.9	.16
July 22-28	162	12.1	.24	19	15.1	.03	251	7.2	.38	133	6.8	.20
July 29-Aug. 4	128	12.1	.17	14	14.3	.02	141	7.3	.19	131	7.2	.18
Aug. 5-11	82	12.3	.13	28	12.2	.04	306	7.6	.48	148	6.7	.24
Aug. 12-18	60	12.3	.09	40	12.8	.06	346	7.1	.54	114	6.7	.18
Aug. 19-25	25	11.3	.09	15	11.7	.05	85	7.0	.30	46	6.9	.16
Aug. 26-Sept. 1	72	11.8	.15	21	13.7	.05	70	7.3	.15	74	6.8	.16
Sept. 2-8	36	11.8	.13	6	12.3	.03	18	7.1	.06	23	6.5	.08
Sept. 9-15	40	13.2	.12	9	12.9	.03	55	6.8	.16	24	7.0	.07
Sept. 16-22	41	13.0	.17	12	11.4	.05	103	7.0	.47	48	6.8	.20
Sept. 23-29	19	13.8	.17	7	14.1	.06	31	7.6	.27	28	6.5	.24
Sept. 30	12	14.8	.22	3	14.7	.05	20	6.8	.36	32	6.3	.58
Total or Ave.	992	12.25	.16	294	13.48	.04	1,970	7.22	.32	1,016	6.83	.16
Per day	10.1			3.0			20.1			10.4		
October	49	14.5	.09	23	13.7	.04	79	7.5	.15	8	7.1	.02
November	1	10.0	.06	—	—	—	1	7.0	.06	2	7	.12
Total or Ave.	50	14.4	.09	23	13.7	.04	80	7.5	.15	10	7.1	.02

Date	Rockbass No. taken	Rockbass Ave. size	Rockbass Per hr.	Perch No. taken	Perch Ave. size	Perch Per hr.	Walleye No. taken	Walleye Ave. size	Walleye Per hr.	Northern Pike No. taken	Northern Pike Ave. size	Bullhead No. taken	Bullhead Ave. size
June 25-30	140	8.7	.44	239	7.4	.76	14	19.0	.04	2	21.0	9	10.0
July 1-7	148	8.2	.39	349	7.3	.93	26	19.9	.07	3	24.7	35	11.0
July 8-14	152	7.9	.28	418	7.3	.77	28	20.8	.05	6	19.5	30	9.9
July 15-21	178	8.8	.37	330	7.6	.68	19	17.8	.04	3	23.0	25	9.2
July 22-28	267	7.5	.40	358	7.6	.54	3	16.2	—	2	21.5	107	10.5
July 29-Aug. 4	197	7.6	.27	287	7.6	.39	6	23.9	.01	2	18.5	12	11.6
Aug. 5-11	276	7.6	.43	265	7.4	.41	8	21.6	.03	9	19.1	21	10.5
Aug. 12-18	247	7.5	.39	220	7.1	.34	7	18.9	.01	2	18.0	42	11.2
Aug. 19-25	114	8.0	.40	199	7.2	.70	2	23.0	.01	—	—	1	12.0
Aug. 26-Sept. 1	184	8.1	.39	253	7.5	.53	2	24.5	—	2	23.5	5	9.6
Sept. 2-8	74	7.9	.26	204	7.5	.71	1	28.0	—	6	24.5	2	11.5
Sept. 9-15	87	7.6	.25	299	7.1	.87	1	18.0	—	4	18.7	9	10.5
Sept. 16-22	47	7.6	.20	207	7.7	.88	1	25.0	—	3	27.3	1	10.0
Sept. 23-29	14	7.8	.13	95	7.9	.83	1	18.0	.01	—	—	3	12.0
Sept. 30	4	7.0	.07	34	7.8	.61	—	—	—	4	26.0	1	12.0
Total or Ave.	2,129	7.9	.34	3,757	7.4	.61	119	20.1	.02	48	21.8	303	10.5
Per day	21.7			38.33			1.2			.49		3.1	
October	68	8.0	.13	1,035	8.0	1.99	4	20.0	.01	6	22.2	3	11.3
November	3	8.0	.18	23	7.4	1.35	—	—	—	1	14.0	—	—
Total or Ave.	71	8.0	.13	1,058	8.0	1.97	4	20.0	.01	7	21.0	3	11.3

*Black crappies, suckers, and shiners were also caught, but were taken in such small numbers that they constituted an insignificant portion of the total catch.

TABLE 4. TOTAL HOURS FISHED AND AVERAGE HOURS FISHED, FIFE LAKE, SUMMER AND FALL OF 1934

Date	Total hours fished	Hours fished, A.M.	Hours fished, P.M.	Time not given	Hours per fisherman-day
June 25-30	316.5	88.5	228	......	2.6
July 1-7	376.0	213.0	161.5	1.5	2.25
July 8-14	539.5	184.0	353.5	2.0	2.4
July 15-21	484.0	224.0	260.0	......	2.6
July 22-28	665.5	300.75	360.75	4.0	2.8
July 29-Aug. 4	739.25	279.0	455.75	4.5	2.8
Aug. 5-11	644.5	207.0	437.5	......	2.5
Aug. 12-18	628.0	233.0	396.0	......	2.4
Aug. 19-25	284.25	112.25	170.0	2.0	2.4
Aug. 26-Sept. 1	474.75	179.5	291.75	3.5	2.35
Sept. 2-8	286.75	90.0	196.75	......	2.45
Sept. 9-15	342.0	66.5	275.5	......	2.9
Sept. 16-22	235.0	104.0	131.0	......	3.4
Sept. 23-29	115.25	53.75	61.5	......	2.7
Sept. 30	55.5	18.5	37.0	......	3.5
Totals or averages	6,187.75	2,353.75	3,816.5	17.5	2.6
October	519.0	135.5	383.5	......	2.7
November	17.0	3.5	13.5	......	2.1
Totals or averages for Oct. and Nov.	536.0	139.0	397.0	......	2.7

ever, about daybreak and about dusk. Relatively few persons fished at the time of day when fishing was best (this is a sample of the information of value to anglers).

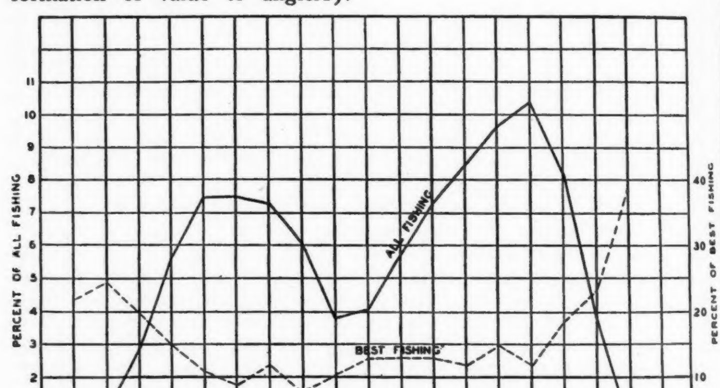


Fig. 3.—Hours when fishing was done, and hours when fishing was best. Fife Lake, summer of 1934.

Methods of fishing and kinds of bait used (see Tables 5, 6 and 7, and Figs. 4, 5 and 6.—More than 90 per cent of the records indicated one method of fishing, either still-fishing, casting, or trolling; 87 per

Table 5. General data on methods of fishing, Fife Lake, summer of 1934

Method	*Reports covering each method** *No.*	*%*	*Fish taken by each method*	*Fish per day's fishing*	*Ave. length of fish (in.)*	*Reports indicating no fish caught* *No.*	*%*
Trolling	221	10	193	.87	14.1	102	46.0
Casting	66	3	58	.88	12.5	28	42.4
Still-fishing	1,919	87	9,504	4.95	8.2	380	19.8

*This computation does not include the 189 records indicating the use of several methods of fishing in one day or not indicating which method was used. These 189 reports gave a total catch of 901 fish, 4.8 fish averaging 8.7 inches long per fishing day. It therefore appears that most of these reports refer to still fishing.

cent of the fishing by a single method was done by one method, still-fishing, which yielded a daily average per person of about 5 fish averaging 8.2 inches long. About one-fifth of the reports on still-fishing showed no catch. The 10 per cent of the fishing which was by trolling produced on the average less than 1 fish per fishing day; almost half of the trolling days yielded no fish at all, but the fish that were caught averaged 14.1 inches in length. Only 3 per cent of the fishing was by casting, and resulted in an average catch of less than one fish, averaging 12.5 inches long, per fishing day; 42.4 per cent of the reports for casting indicated no fish caught. Obviously the method which produced most fish per fisherman yielded fish averaging the smallest. This was not unexpected, a method which produces numerous large fish would soon be used almost universally.

Table 6. General data on effectiveness of various kinds of bait used, Fife Lake, summer of 1934

Bait used	*No. of records*	*% getting no fish*	*Hrs. per fishing day*	*No. of fish taken*	*Fish per hour*	*Ave. size of all fish (in.)*
ARTIFICIAL:						
Spinner	102	33	2.3	197	0.9	12.5
Plug	75	39	2.4	86	0.5	14.5
Artificial fly	10	50	2.1	23	2.3	8.2
NATURAL:						
Minnows	857	17	2.7	4,336	1.9	8.4
Worms	832	17	2.5	3,936	1.9	7.8
Grasshoppers	27	33	3.1	140	1.7	9.3

Six kinds of bait were listed, three artificial (spinner, plug, and artificial fly), and three natural (minnows, worms, and grasshoppers). Spinners, indicated as used exclusively by 102 reports, produced per hour, on the average, almost one fish; the fish so caught had an average length of 12.5 inches; a third of the spinner-fishing records showed no catch. Plugs, used exclusively on 75 fishing days, yielded only one-half fish per hour, but these averaged 14.5 inches; more than one-third of the fishing records for plugs listed no fish at all. Artificial flies were used so little, that the figures available have little significance.

Minnows, used exclusively on 857 fishing days, produced per hour 1.9 fish, having an average length of 8.4 inches. Worms were almost identical with minnows in effectiveness, except that they produced fish of a slightly smaller average size (7.8 inches). Grasshoppers, used very little as bait, were almost as effective as worms or minnows and produced fish of a large average size. As expected, the number of fish taken per hour by different types of bait was inversely proportional to the average size of fish taken, and the larger the average size of fish taken, the less was the chance of getting any fish at all.

TABLE 7. ANALYSIS OF CATCH (BY SPECIES) ON VARIOUS KINDS OF BAIT. FIFE LAKE, SUMMER OF 1934

	All species	Largemouth bass	Smallmouth bass	Rock bass	Bluegills	Sunfish	Perch	Walleyes	Northern pike	Bullheads
ARTIFICIAL BAIT										
Spinner:										
Number caught	197	41	44	35	20	10	12	27	8	—
Average size	12.5	13.4	13.1	9.0	7.6	7.7	9.8	19.1	20.1	—
Catch per hr.	.09	.18	.19	.15	.09	.04	.05	.12	.03	—
Plug:										
Number caught	86	20	22	6	2	—	14	18	4	—
Average size	14.5	15.2	13.3	8.3	10.0	—	7.8	21.7	20.0	—
Catch per hr.	.05	.11	.12	.03	.01	—	.08	.10	.02	—
Artificial Fly:										
Number caught	23	—	2	2	12	1	4	—	—	—
Average size	8.2	—	11.0	8.0	8.6	7.0	7.5	—	—	—
Catch per hr.	2.3	—	.10	.10	.57	.05	.19	—	—	—
NATURAL BAIT										
Minnows:										
Number caught	4,336	110	459	724	603	336	1,943	18	22	101
Average size	8.4	13.0	12.5	7.9	7.4	6.8	7.6	19.7	23.0	9.7
Catch per hr.	1.9	.05	.20	.31	.26	.14	.84	.01	.01	.04
Worms:										
Number caught	3,936	47	234	901	926	572	1,106	5	6	137
Average size	7.8	12.2	11.8	8.0	7.1	6.9	7.2	20.8	18.8	11.4
Catch per hr.	1.9	.02	.11	.44	.45	.28	.54	trace	trace	.07
Grasshoppers:										
Number caught	140	11	14	48	53	—	14	—	—	—
Average size	9.3	16.9	11.6	8.8	7.7	—	8.4	—	—	—
Catch per hr.	1.7	.13	.17	.58	.64	—	.17	—	—	—

Largemouth bass were most successfully taken on artificial bait; on the average, spinners yielded most largemouths per unit time, plugs took the largest (results on grasshoppers and artificial flies are not considered in this statement or in subsequent remarks). Smallmouth bass were taken with almost equal success on natural and artificial bait, although artificial bait took fish of a larger average size. Largemouth and smallmouth bass showed a decided difference in their response to the several kinds of bait (see Fig. 4). Perch were mostly taken on minnows; walleyes responded chiefly to artificial bait; northern pike were taken also most frequently on artificial bait, but the largest ones, on the average, were caught on minnows (Fig. 5). Rockbass,

bluegills and sunfish were most successfully fished for with worms as bait (Fig. 6).

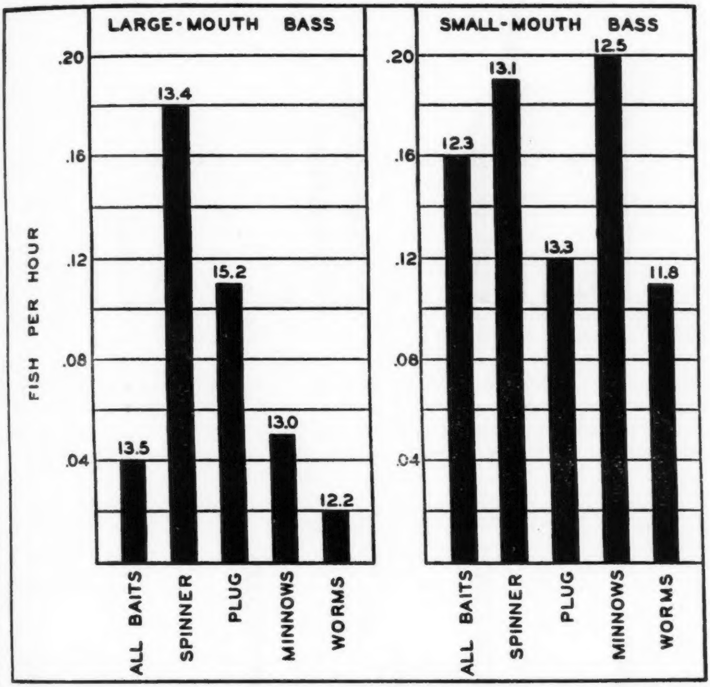


Fig. 4.—Catch, in terms of fish per hour, of large-mouth bass and small-mouth bass on all baits and on each of four different kinds of bait. Summer of 1934, Fife Lake. Figures at the top of each column show the average size, in inches, of fish caught.

Relation between fishing and weather (chart omitted).—Such creel census may also be used to test the relationship between fishing and weather, and this was done for the Fife Lake census. For each day of July and August, the per-hour catch data for all fish and for each of 5 species were plotted on a chart. Barometric pressure for each day, prevailing wind direction, temperature at 6:00 P. M. and median daily temperature, condition of sky (whether clear, partly cloudy, or cloudy), and precipitation, were then plotted on the same graph. A preliminary examination of this chart fails to indicate a close relationship between fishing and any one of the several meteorological factors

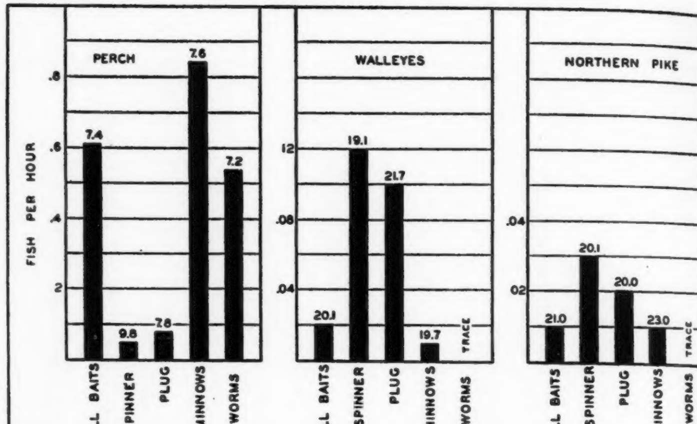


Fig. 5.—Catch, in terms of fish per hour, of perch, walleyes, and northern pike on all baits and on each of four different kinds of bait. Fife Lake, summer of 1934. Figures at the top of each column show the average size, in inches, of fish caught.

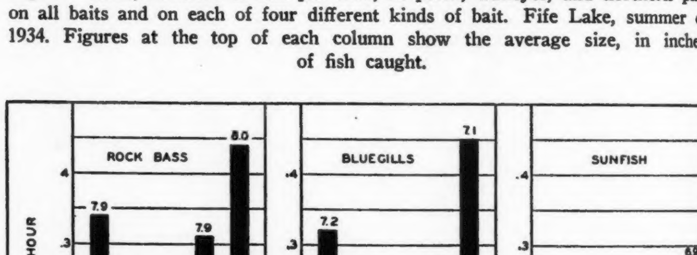


Fig. 6.—Catch, in terms of fish per hour, of rock bass, bluegills, and sunfish on all baits and on each of four different kinds of bait. Fife Lake, summer of 1934. Figures at the top of each column show the average size in inches of fish caught.

which were considered, and therefore apparently fails to lend any considerable support for any one of these theories, although it does not alone and conclusively disprove these supposed relations.

Relation between fishing by residents and visitors.—Although the Fife Lake creel census of 1934 did not involve the necessary data, such a census can be used to compare the fishing by local and visiting anglers. Such comparisons, now being made on census for Fife and other lakes, will provide data bearing on the frequent local controversies between these two groups of fishermen.

Fall Fishing

Fall fishing, which is here considered as restricted to the months of October and November, and data for which are included in some of the preceding tables for summer fishing, are shown by the creel census to be characterized by the following features, among others. Less fishing was done in Fife Lake during the entire fall than in almost any one week in mid-summer; only 190 fishing days in October and 8 in November were listed. Fewer fishing days yielded no fish at all in the fall than in the summer, but as in the summer, fewer women than men, proportionally, had complete failures. No limit catches were made in the fall, but on a fish per hour basis, fall fishing was much better than summer fishing. Perch, constituting 80 per cent of the total fall catch, were then taken at the average rate of two fish per hour. Fall fishing was all still-fishing, with the exception of a very few hours of trolling, and was concentrated in the late morning and the early and mid-afternoon, probably because of warmer air temperature at those hours.

Winter Fishing (Table 8)

TABLE 8. COMPARISON OF LINE FISHING AND SPEARING ON FIFE LAKE, DEC. 21 TO APR. 4, 1933-1934, AND DEC. 1-20, 1934

	Line Fishing	Spearing	Total or Average
Hours fished	715.5	1,382.75	2,098.25
Number of fishermen	142	332	474*
Average hours per fisherman-day	5.0	4.2	4.5
Fish caught	154	132	286
Fish per hour	.215	.095	.13
Hours per fish	4.6	10.4	7.3
Fish per fisherman-day	1.1	.4	.6
Perch	133	------	133
Walleyes	5	1	6
Northern pike	13	103	116
Bullheads	------	17	17
Common suckers	------	11	11
Shiners	3	------	3
Average size of all fish	11.8	22.8	16.9

*7 used both lines and spears and were considered separately under each. The actual number of fisherman-days was 467.

The winter records, taken for the fishing from December 21, 1933, to April 1, 1934, and December 1 to 20, 1934, thus covering one full winter period though taken in two winters, yielded a number of important conclusions regarding fishing at that season. Winter fishing consisted chiefly of spearing, only one-third of line-fishing. The total winter fishing covered 2,098.25 hours, on 474 fishing days, an average

of 4.5 hours per day. The 142 line-fishing days yielded 154 fish, while the 332 spear-fishing days produced only 132 fish. Fish were taken at the rate of about 1 every 5 hours with lines and 1 every 10 hours with spear. Each day of line fishing yielded an average of one fish; each day of spearing an average of less than half a fish. Seventy per cent of all the winter reports showed no fish caught. The spearing chiefly produced northern pike, while line fishing mostly yielded perch. The average length of all fish caught with lines was 11.8 inches, with spear 22.8 inches, while the average length for all winter-caught fish was about 17 inches. There were no limit catches. All fishing was between 9:00 A. M. and 5:00 P. M. The catch was so meager that a "best fishing" curve could not be made. Only 14 of the winter reports were for women, who caught a total of one fish, a northern pike.

Comparison of the Fishing in Different Seasons (Table 9, first 3 columns).—Of the total of 9,318.5 fisherman-hours in Fife Lake for the year, ending December 20, 1934, 22.5 per cent was in winter, 71.6 per cent in the summer, and 5.9 per cent in fall. The records show 467 fisherman-days in the winter (14.4 per cent), 2,570 in the summer (79.4 per cent), and 201 in the fall (6.2 per cent). The average number of hours per fisherman-day was 4.5 for the winter, almost twice as many as in summer (2.6) or fall (2.7): people fished longest at a season when the weather was the least pleasant and when there was the least probability of catching fish. Of the total of 13,072 fish caught (not including 74 fish for which the lengths were not given), 2.2 per cent were taken in winter, 87.7 per cent in summer and 10.1 per cent in the fall. Almost a fourth of the fishing was in winter but only a little more than one-fiftieth of the fish were caught during that season. The average catch per person per day was 0.6 in the winter, 4.4 in the summer and 6.6 in the fall; the average catch per hour was 0.13 in the winter, 1.72 in the summer and 2.43 in the fall. The fish caught, in the winter, however averaged approximately twice as long as those taken in the other seasons.

Perch, which constituted two out of every five of the fish taken, were caught most commonly in the fall, very seldom in the winter; rockbass were mostly taken in the summer, and bluegills were decidedly summer-caught fish. No comparison of the winter and summer fishing for smallmouth and largemouth bass was obtained, because the season is closed for these species in the winter. Northern pike were mostly caught in the winter. Fishing for both pike and perch was poor during the heat of summer.

Winter fishing was extensive in terms of hours fished. Shanties on the ice and men fishing with four or five ice lines each are conspicuous. It is not to be wondered at that many resorters feel that the winter fishing is responsible for poor summer fishing. When the actual catch records are taken into consideration, however, it is obvious that the winter fishing in Fife Lake could not have been injurious to fishing during the following summer.

TABLE 9. COMPARISON OF FISHING IN DIFFERENT SEASONS AND FOR THE WHOLE YEAR (DEC. 21, 1933-DEC. 20, 1934)

	Winter Dec. 1-Apr. 4	Summer June 25-Sept. 30	Fall Oct. and Nov.	Entire Year	Per Acre
s fished	2,098.25	6,187.75 (+488.5)[1]	536 (+8)[1]	9,318.5[1]	11.65
of total	22.5	71.6	5.9	———	———
of fisherman-days	467	2,399 (+181)	198 (+3)	3,248	4.06
of total	14.4	79.4	6.2	———	———
s per fisherman-day	4.5	2.6	2.7	2.9	———
f fish	286	10,656 (+804)	1,306 (+20)	13,072[2]	16.33
of total	2.2	87.7	10.1	———	———
per fisherman-day	.6	4.4	6.6	4.0	———
per hr.	.13	1.72	2.43	1.4	———
size of all fish (in.)	16.9	8.33	8.4	8.5	———
H[3]					
mber	133	3,755 (+283)	1,058 (+16)	5,247	6.55
total catch	46.5	35.24	80	40.1	———
rch per hour	.06	.61	1.97	.56	———
erage size	9.0	7.4	8.0	7.6	———
K BASS					
mber	———	2,129 (+160)	71 (+1)	2,361	2.95
total catch	———	20.0	5.4	18.1	———
ck bass per hour	———	.34	.13	.25	———
erage size	———	7.9	8.0	7.9	———
EGILL					
umber	———	1,970 (+148)	80 (+1)	2,199	2.75
total catch	———	18.49	6.2	16.8	———
uegills per hour	———	.32	.15	.24	———
erage size	———	7.2	7.5	7.2	———
ALLMOUTH BASS					
mber	———	992 (+74)	50 (+1)	1,117	1.40
total catch	———	9.31	3.8	8.5	———
nallmouth bass per hour	———	.16	.09	.12	———
verage size	———	12.25	14.4	12.3	———
NFISH					
umber	———	1,016 (+76)	10	1,102	1.38
total catch	———	9.53	.8	8.4	———
nfish per hour	———	.16	.02	.12	———
verage size	———	6.8	7.1	6.8	———
LLHEAD					
umber	17	303 (+23)	3	346	0.43
total catch	5.9	2.84	—	2.6	———
ullheads per hour	.008	.05	—	.03	———
erage size	12	10.5	11.3	10.6	———
RGEMOUTH BASS					
umber	———	294 (+22)	23	339	0.42
total catch	———	2.76	1.8	2.6	———
rgemouth bass per hour	———	.04	.04	.03	———
verage size	———	13.5	13.7	13.5	———
RTHERN PIKE					
umber	116	48 (+4)	7	175	0.22
total catch	39.9	.45	—	1.3	———
ke per hour	.05	.01	—	.015	———
verage size	25.4	21.8	21	24.1	———
LLEYE					
umber	6	119 (+9)	4	138	0.17
KER					
umber	11	9 (+1)	—	21	0.03
CK CRAPPIE					
umber	———	15 (+1)	—	16	0.02
NER					
umber	3	4	—	7	0.01

[1] The figures in parenthesis, for fishermen seen but not directly contacted, for those whose fishing incorrectly recorded and for those whose records were lost, were used in the total catch and in percentage computations, on the assumption that these fishermen made average catches.

[2] Seventy-four additional fish were recorded, for which the length was lacking. These included llmouth bass (1), rock bass (16), bluegills (19), sunfish (9), perch (25) and bullheads (4); and were included in the calculations.

[3] Species taken in order of their abundance in the catch.

The annual fish crop (see Table 9, last 2 columns).—The creel census being reported upon gives us perhaps the most reliable data on the fishing intensity and on the annual fish crop, available for any public lake in America devoted to sport fishing. On this 800-acre average Michigan lake, a total of more than 9,300 hours of fishing were spent in one year, an average of 11.65 per acre (since most of the lake area was of unsuitable depth, the fishing intensity on the actual fishing grounds was of course much greater). The fisherman days numbered 3,248 (about 4 per acre). This fishing yielded more than 13,000 fish averaging 8.5 inches,—1.75 miles of fish laid end to end. The average yield of fish per hour was 1.4, or 4.0 per fishing day averaging 2.9 hours. Perch (5,247 taken) constituted about 40 per cent of the annual harvest, rock bass 18 per cent, bluegills 17 per cent, smallmouth bass and sunfish about 8.5 per cent each, bullheads and largemouth bass 2.6 per cent, northern pike 1.3 per cent, walleyes 1.1 per cent; suckers, black crappies and shiners in insignificant proportion. The fish crop of this lake is therefore a diversified one. The yield per acre was 6.55 for perch, and proportionately less for the other species taken. The total yield of all fish was 16.3 per acre, perhaps about 10 pounds per acre, considering the entire area of the lake (the poundage per acre will be computed after the length-weight relation has been established for the various species caught).

Creel Census as an Aid in Fish Management

It is obvious that the information determined by such a creel census is potentially of great value in fish management. An adequate inventory will surely be required before fish management can be placed on a business-like basis. A few of the ways by which fish management of inland lakes could be benefited by a thorough creel census are:

1. Determinations of the trend of the fishing returns for the various species caught, determined over a period of years, will indicate what need be done to maintain or increase the fish crop, and the maximum annual crop which may be harvested without injury to the future fishing.

2. The determination of the number of undersized fish taken, coupled with the growth rate studies, will allow predictions to be made of the catch which may be expected for the following few years.

3. The creel census can be used to determine the effectiveness of existing legal restrictions and, in over-fished waters, would help to indicate what restrictions will be of greatest benefit to the lake and the least objectionable to the fisherman. It is entirely possible that the present size limits and bag limits on some species are definitely injurious to the fishing as a whole.

4. A creel census coupled with fish-marking would indicate the number of adult fish in the lake, and the percentage of adult fish removed annually.

5. Coupled with planting and tagging experiments, the census could provide data sufficient to evaluate the benefits derived from stocking.

6. Coupled with lake improvement, the census could similarly be made to indicate, in time, what benefits if any are derived from the improvement work in general, and from improvement devices of different sorts.

7. If carried out on a representative number of lakes of various types and sizes, and if the area of the lakes of a state is determined, the creel census could be used to indicate the approximate annual catch of game fish for the state. If acreage determinations for Michigan lakes are correct, and if Fife Lake fishing was exactly average, the inland lakes of Michigan produced in 1934 a total of 13,500,000 legal-sized fish. If the fish taken from all the lakes averaged the same as for Fife Lake, they have a total length of 1800 miles, approximately equal to the air line distance from southwestern Michigan to Los Angeles, California. Obviously this estimate of total production can not be determined with any reasonable accuracy from the census on one lake, but is mentioned to indicate the sort of inventory of the total game fish catch of the inland lakes in the state which could be made with considerable accuracy provided the creel census was materially expanded.

8. The investigations of the Institute for Fisheries Research lead us to believe that a reasonably sound stocking policy for inland lakes, including a stocking budget, could be formulated by a combination of an extensive creel census with an inventory and classification of the lakes and with biological studies, especially with the determination of the growth rates of the different species in various lakes.

THE 1935 TROUT HARVEST FROM FURNACE BROOK, VERMONT'S "TEST STREAM"

RUSSELL F. LORD

U. S. Fisheries Experimental Trout Hatchery, Pittsford, Vermont

I believe that never before have so many people sought the trout streams, not only for the sake of the sport itself, but to escape from the countless worries that assault them on all sides. There is plenty of leisure today, desired or otherwise, roads are good, someone can usually be counted upon to provide a car—so why not go fishing again? Well, why not indeed!

Trout fishing, in my mind, is a recreational outlet bringing a satisfaction that can not be measured in dollars and cents. At the same time it requires dollars and cents, and lots of them, for the sport to exist at all, so now we are finding ourselves in a lamentable position where the money for rearing trout is scarce and the would-be catchers of trout never more abundant.

It is a tough problem for even the most efficient of the efficiency experts to tackle. The obvious thing to do is to try and get the most value out of our trout-fishing dollars, and that takes in a great deal of territory. What it means is that every step in the production of our annual trout harvest should follow the path of maximum efficiency, which is just another way of demanding better hatchery methods, better stocking methods and better legislation for regulating the taking of the fish.

I will not at this time consider the problem confronting the active fish culturists of the country. Sufficient to say that the problems exist, and that much has been accomplished within recent years toward improving fish cultural practices. I wish as much could be said for the actual stocking of the streams and for the regulations passed by different states for the conservation of their game fish.

Without the stocking done in the past our streams and lakes today would be filled with a vast emptiness as far as game fish are concerned, and credit must be given to all those who have taken part in the work. Yes, the waters have been stocked, but such planting of fish has in the main been carried out with no definite plan in mind. Anyone today can put in an application for fish, describe the body of water in terms that suit himself, and dispose of his allotment of trout practically as he wishes. I still recall one instance when the application stated that the pond in question was suitable trout water and my thermometer registered 80° F. when I tested it. Incidentally the starved-looking bass some eight inches in length that hopefully hurried over to the shining metal case of the instrument to see if it was edible, did nothing to impress the ob-

server that here was an ideal habitat for brook trout fingerlings. In fact the pond, hardly more than a puddle at that, was swarming with undersized bass and scores of pumpkin-seeds.

Such examples are of course extreme, but it goes without saying that it is useless to rear trout to be planted anywhere at the whim of an applicant. When our hatcheries, both government and state, and some of the sportsmen's associations are striving hard to provide the public with something to catch, it is only good business to place the fish where they will have the best opportunity to give an account of themselves. The recent stream and lake surveys carried out by certain states and by the Bureau of Fisheries are one way of gaining reliable information as to what fish should be planted in the different types of waters. Just a few days ago, I showed an applicant what the 1934 survey said about a lake where he intended to plant some rainbow fingerlings, with the result that the fish went elsewhere and the pickerel and rock bass already in the pond had to look for other delicacies than hatchery trout.

Supposing, however, that the question of the right kind of fish for the place in mind has been satisfactorily settled, are we much better off? Not at all! The number and size of trout to be planted, despite the efforts of several investigators, is still largely a matter of guess work. So are the regulations designed to protect the future of the fish. It is a fact none the less, that stocking and fishing regulations are here to stay, so the only sensible thing to do is to see that the kind of stocking done and the kind of laws enforced are really designed for the purpose of securing bigger and better annual trout harvests.

And right here we hesitate, for no one on earth knows what a typical annual trout harvest from a good trout stream should be, or even has a sane notion of how many fish are being removed each season. For several years I have entertained the hope that some time a way would be found to set aside certain typical trout waters as proving grounds to ascertain what a normal trout production should be, and what was the relationship between the planting of different sized fish and the subsequent catch. It is relatively easy to keep track of the fish that go into a stream, but finding out how many are removed is a different matter!

In other words, unless some scheme can be devised for obtaining angling statistics in different waters, the agencies engaged in keeping up the fish can keep right on working until Doomsday without any real idea of what they were really up against. Thus at the Pittsford Station there have been in the past several attempts to secure fishing statistics, by asking for voluntary co-operation from the fishermen. Fishermen however are somewhat loath to reveal much about their luck, especially if it is good, and hence the system of voluntary reports did not amount to much. For example during the summer of 1934 only 129 reports on fishing results in Furnace Brook were received.

The subject was taken up with the Vermont Fish and Game Service

and with certain sportsmen's associations, with the result that the 1935 Assembly of the State of Vermont passed a bill making it possible for the state fish and game service to co-operate with the Bureau of Fisheries in a program of "test water" investigation. The bill provides that up to four different bodies of "test waters" can be set aside in the state at any one time to be used in an investigation to determine the annual trout production. The Bureau of Fisheries is to carry on the necessary stocking and scientific work while the state fish and game service is to see that the regulations pertaining to the "test waters" are enforced. All fishermen are required to obtain a permit, issued without charge, and are required by law to report the daily catches on cards provided for that purpose in boxes at certain points along the test area in question. Violators are liable to a $10.00 fine.

During the past season just one stream, Furnace Brook, which flows through the hatchery grounds at Pittsford, was selected as a test stream. This is an excellent trout brook with plenty of food and shelter. It is about twenty-five feet in width throughout the four miles of stream selected as the test area. A road follows it to the headwaters. As it is within a few miles of several cities and towns it is very heavily fished each season.

TABLE 1. MAY SUMMARY. FISHING RESULTS, FURNACE BROOK, 1935

Date	Legal Brook	Legal Rainbow	Daily total both	Grand total Brook	Grand total Rainbow	Grand total both kinds
May 1	568	239	807	568	239	807
May 2	120	23	143	688	262	950
May 3	105	17	122	793	279	1,072
May 4	272	54	326	1,065	333	1,398
May 5	433	69	502	1,498	402	1,900
May 6	52	18	70	1,550	420	1,970
May 7	2	7	9	1,552	427	1,979
May 8	53	15	68	1,605	442	2,047
May 9	53	19	72	1,658	461	2,119
May 10	82	25	107	1,740	486	2,226
May 11	83	25	108	1,823	511	2,334
May 12	103	26	129	1,926	537	2,463
May 13	34	22	56	1,960	559	2,519
May 14	62	11	73	2,022	570	2,592
May 15	6	4	10	2,028	574	2,602
May 16	31	30	61	2,059	604	2,663
May 17	68	38	106	2,127	642	2,769
May 18	57	61	118	2,184	703	2,887
May 19	21	32	53	2,205	735	2,940
May 20	9	1	10	2,214	736	2,950
May 21	1	8	9	2,215	744	2,959
May 22	15	37	52	2,230	781	3,011
May 23	22	24	46	2,252	805	3,057
May 24	56	55	111	2,308	860	3,168
May 25	45	65	110	2,353	925	3,278
May 26	119	116	235	*2,472	1,041	3,513
May 27	19	26	45	2,491	1,067	3,558
May 28	26	21	47	2,517	1,088	3,605
May 29	148	51	199	2,665	1,139	3,804
May 30	79	72	151	2,744	1,211	3,955
May 31	26	4	30	2,770	1,215	3,985

Number of fishing reports for above fish: 614. **Percentage Brook trout: 70**
Average number of fish per attempt: 6.49. **Percentage Rainbows: 30.**

NOTE: By May 26th the total number of brook trout removed surpassed the number of legal fish planted the previous September. This shows that stocking merely supplements natural spawning in a good trout stream.

The number of rainbows taken is interesting in that this species is not being stocked in Furnace Brook and holds its position due to natural spawning.

*2,400 legal brook trout were planted the previous September.

TABLE 2. JUNE SUMMARY. FISHING RESULTS, FURNACE BROOK, 1935

Date	Legal Brook	Legal Rainbow	Daily total both	Grand total Brook	Grand total Rainbow	Grand total both kinds
June 1	30	43	73	2,800	1,258	4,058
June 2	54	53	107	2,854	1,311	4,165
June 3	8	22	30	2,862	1,333	4,195
June 4	17	19	36	2,879	1,352	4,231
June 5	51	42	93	2,930	1,394	4,324
June 6	30	56	86	2,960	1,450	4,410
June 7	16	32	48	2,976	1,482	4,458
June 8	25	46	71	3,001	1,528	4,529
June 9	77	39	116	3,078	1,567	4,645
June 10	20	5	25	3,098	1,572	4,670
June 11	21	31	52	3,119	1,603	4,722
June 12	34	19	53	3,153	1,622	4,775
June 13	63	71	134	3,216	1,693	4,909
June 14	38	14	52	3,254	1,707	4,961
June 15	63	55	118	3,317	1,762	5,079
June 16	67	58	125	3,384	1,820	5,204
June 17	14	4	18	3,398	1,824	5,222
June 18	13	19	32	3,411	1,843	5,254
June 19	35	8	43	3,446	1,851	5,297
June 20	48	6	54	3,494	1,857	5,351
June 21	99	28	127	3,593	1,885	5,478
June 22	94	29	123	3,687	1,914	5,601
June 23	54	18	72	3,741	1,932	5,673
June 24	17	8	25	3,750	1,940	5,698
June 25	16	4	20	3,774	1,944	5,718
June 26	17	8	25	3,791	1,952	5,743
June 27	32	45	77	3,823	1,997	5,820
June 28	21	2	23	3,844	1,999	5,843
June 29	74	30	104	3,918	2,029	5,947
June 30	70	23	93	3,988	2,052	6,040

Number of fishing reports for above fish: 257.
Average number of fish per attempt: 7.99.
Total June Catch: 2,055 (May catch about twice as many).

TABLE 3. JULY SUMMARY. FISHING RESULTS, FURNACE BROOK, 1935

Date	Legal Brook	Legal Rainbow	Daily total both	Grand total Brook	Grand total Rainbow	Grand total both kinds
July 1	33	27	60	4,021	2,079	6,100
July 2	13	5	18	4,034	2,084	6,118
July 3	20	12	32	4,054	2,096	6,150
July 4	74	47	121	4,128	2,143	6,271
July 5	—	4	4	4,128	2,147	6,275
July 6	29	13	42	4,157	2,160	6,317
July 7	12	11	23	4,169	2,171	6,340
July 8	11	1	12	4,180	2,172	6,352
July 9	12	5	17	4,192	2,177	6,369
July 10	12	3	15	4,204	2,180	6,384
July 11	6	10	16	4,210	2,190	6,400
July 12	26	26	52	4,236	2,216	6,452
July 13	18	20	38	4,254	2,236	6,490
July 14	81	71	152	4,335	2,307	6,642
July 15	5	3	8	4,340	2,310	6,650
July 16	14	18	32	4,354	2,328	6,682
July 17	17	27	44	4,371	2,355	6,726
July 18	36	20	56	4,407	2,375	6,782
July 19	15	27	42	4,422	2,402	6,824
July 20	22	14	36	4,444	2,416	6,860
July 21	114	12	126	4,558	2,428	6,986
July 22	26	27	53	4,584	2,455	7,039
July 23	19	28	47	4,603	2,483	7,086
July 24	16	4	20	4,619	2,487	7,106
July 25	67	16	83	4,686	2,503	7,189
July 26	47	29	76	4,733	2,532	7,265
July 27	58	32	90	4,791	2,564	7,355
July 28	87	46	133	4,878	2,610	7,488
July 29	117	18	135	4,995	2,628	7,623
July 30	24	12	36	5,019	2,640	7,659
July 31	58	14	72	5,077	2,654	7,731

Number of reports for above fish: 211.
Average number of fish per attempt: 8.
Total number of July caught trout: 1,691.

TABLE 4. AUGUST SUMMARY. FISHING RESULTS, FURNACE BROOK, 1935

Date	Legal Brook	Legal Rainbow	Daily total both	Grand total Brook	Grand total Rainbow	Grand total both kinds
August 1	44	5	49	5,121	2,659	7,780
August 2	62	26	88	5,183	2,685	7,868
August 3	10	15	25	5,193	2,700	7,893
August 4	71	27	98	5,264	2,727	7,991
August 5	50	35	85	5,314	2,762	8,076
August 6	32	21	53	5,346	2,783	8,129
August 7	74	21	95	5,420	2,804	8,224
August 8	40	24	64	5,460	2,828	8,288
August 9	61	44	105	5,521	2,872	8,393
August 10	62	25	87	5,583	2,897	8,480
August 11	29	7	36	5,612	2,904	8,516
August 12	4	8	12	5,616	2,912	8,528
August 13	....	7	7	5,616	2,919	8,535
August 14	31	23	54	5,647	2,942	8,589
End of Trout Season for 1935.						

Number of fishing reports for above fish: 115.
Average number of fish per attempt: 7.46.
Total number August caught fish: 858.

Before the fishing season opened on May 1, 1935, a large sign was placed in position at the beginning of the test section, stating the "test water" regulations. Mail boxes, painted a brilliant red to attract attention, were set up in strategic positions along the brook, each box containing a supply of mimeographed cards for the use of anglers in recording their daily catches.

Grand Summary

Rainbow trout made up 34 per cent of the total season's catch. This species is maintaining itself without stocking.

Brook trout made up 66 per cent of the total season's catch. If all of the fish planted in September, 1934, were taken, they made up 27.9 per cent of the brook trout caught. 72.1 per cent of the total number of brook trout caught had to be wild trout.

1,197 fishing reports were tallied for the grand season catch of 8,589 trout. Average number of fish per attempt during the season was 7.2 trout.

The number of fishermen progressively declined during the months of the season but the average catch held up very well. Although the May catch was high, most of the fish represented a waste as they were in poor condition. The competition made each fisherman's average lower than in the other months.

Although it was realized that Furnace Brook was being heavily whipped each season, the final tally of legal trout removed was none the less imposing. The figures illustrate better than words the fishing intensity in these places easily accessible. It was anticipated that the advertising given the "test-stream" would result in subsequent overfishing by anglers from a wide area. The advertising, however, appeared to have the opposite effect, for would-be fishermen on learning of the thousands of trout removed during the first month of fishing decided that the other fellows had them all and went elsewhere. Thus the stream was really not fished as hard as in other years after all.

The fact remains however that it is just this sort of heavy fishing that is surely depleting the trout supply in our brooks.

The question still remains, "Has the test-stream suggested any way to get more value out of that trout-fishing dollar mentioned earlier in this paper?" The answer is, "Yes."

The test stream figures do suggest certain outstanding modifications of the existing fishing regulations. Before mentioning these modifications it might not be amiss to picture just what goes on each year in a Vermont mountain stream such as Furnace Brook. Let us suppose the trout season has ended for the summer. Those fish (brook trout) fortunate enough to have escaped the anglers during the summer's heavy fishing, and heavy feeding, are ready to spawn in October. At this time they are fat, vigorous fish in excellent condition, well-fitted for the general hard work of the spawning season.

As the spawning season advances they become too busy for foraging and start losing weight. They never regain condition again until warm weather, for their activity is dependent upon the water temperature. Rarely does a Vermont stream stay warm enough to allow much winter feeding. Instead the trout depend upon the fats and oils stored in their bodies during the season of plenty and instead of growing they actually lose weight.

And then what happens! The ice goes out. Snow water comes roaring down from the mountains and the trout all collect in the deeper pools where there is better shelter from the torrent. And there they are when the first of May fishermen get busy—concentrated in the pools, hugging the bottom, sluggish, thin fish as far removed from summer-caught trout in fight and flavor as lowly suckers. A fifteen-inch fish with a hook snagged in his gullet and a half-dozen shot dangling from the snell does little but shake itself protestingly as unskilled hands drag it through the icy water. In summer on a number twelve fly the same fish would make an expert angler feel as if he had hooked into so much dynamite.

But in Vermont, the first of May finds everyone who is at all able-bodied prowling along the icy streams for the sole purpose of catching as many of those thin, under-weight, poorly-flavored trout as possible before the other fellows get them first. This past season no less than a dozen fishermen sought the shelter of my fireside to thaw out sufficiently to bait a hook. By no stretch of the imagination can this early fishing be called skill, but human nature is human nature and we are all at it . . . we fellows who would sooner catch one trout on a fly than ten on a worm, all trying to get our share of imitation-trout merely because the laws says we may and the competition keen. It seems to me that a game fish should really be taken by game fish methods, but the early trout season allows anyone able to hold a rod to sit by a deep pool and catch as many as ten trout, providing he does not freeze to death in the process. Is this getting the most for our trout fishing dollar?

The very fact that in many northern states the trout season opens so early is responsible in the main for a heavy removal of fish at a time when they fall short of providing the maximum in pleasure, sport or food. It really seems a very poor way to treat our limited supply of a splendid game fish like the trout. There are plenty of fish—perch, rockbass, pickerel, bullheads, pike and so on, to provide sport for the bait fishermen, but only the trout family and the bass respond readily to the artificial fly. As it is now, by the time fly fish comes around, the best fish have already gone home in the baskets of the early horde of worm-drowners! I do not wish to be understood as saying that the fly fishermen do not take fish—quite the contrary. But they really get the very best the trout have to offer, from the rise to the frying pan, and after all, we are trying to get the most for the trout-fishing dollar, remember!

I do not believe that any one having the future of trout fishing at heart can look at the figures of the 1935 trout harvest from Furnace Brook without realizing that some fishing should be done. Just what is a matter of some discussion. As far as Vermont and other northern states are concerned, it would seem that a later season and a smaller creel-limit should be in order. Surely a season from the first of June until the end of August would go a long way in the process of getting more value on our trout harvest. The fish by then would act like trout and taste like trout. New green leaves, sunshine sparkling an the riffles, and the smell of growing things all around, seems to me much better than the snow flurries, shivers and red noses of May 1. And surely a reduction in the creel-limit from twenty-five to fifteen trout would not bother any sportsman worthy of the name! Why ruin the streams by overfishing? The figures secured on Furnace Brook, while astounding, merely represent a normal season's fishing. Each year this stream and other streams are fished as hard, and each succeeding season finds fewer trout available. They can not be made by some automatic machine that generates them as fast as they are removed by anglers.

It is realized, of course, that only one season's angling statistics have been secured, but, even so, these figures show what a real job the agencies engaged in keeping up the fishing have on their hands. Over 8,500 legal trout removed from approximately four miles of stream annually! The take of brook trout exceeded the number of fish planted before the first fishing month was over! Can we rear enough trout to meet such an annual drain? We can not do it without adequate funds and every penny spent for rearing trout, for stocking streams, for enforcing regulations must be spent as wisely as possible. Perhaps in time such investigations as the Vermont "test-water" program will give us a much better idea of how to get the most out of the trout-fishing dollar. Perhaps in time the relationship between the number and size of trout planted and the subsequent harvest will be better understood. In the meantime, it is apparent that our streams are being fished intensely and that moderation seems to be in order.

In conclusion I would like to bring in a happy ending, but it seems to me that good fishing at home is doomed unless everyone engaged in the production—and in the catching—of trout wakes up.

Summary

1. The 1935 Assembly of the State of Vermont passed a bill giving the Fish and Game Service authority to co-operate with the Bureau of Fisheries in an investigation designed to determine the trout production of different waters.

2. The bill in essence states that "test waters," up to four in number, may be reserved solely for the purpose of securing angling statistics. Fishermen are required by law to report all fish taken therein. A permit, issued free of charge, must be secured for fishing test waters. The Bureau of Fisheries oversees the stocking, carries on the necessary scientific research, and the Vermont Fish and Game Service enforces the fishing regulations. Violators of the regulations are liable to a $10.00 fine.

3. One stream, Furnace Brook, was selected as a test stream during 1935.

4. 1,197 fishing reports were tallied. 8,589 legal trout were taken from the stream between May 1, 1935, and August 14, 1935, inclusive. The anglers averaged 7.2 trout per fishing attempt. Rainbows made up 34 per cent of the catch. This species is maintaining itself without stocking. Brook trout made up 66 per cent of the catch. The number of brook trout taken exceeded the number of fish planted before the first fishing month was over.

5. The first season's returns on the "test stream" shows conclusively the intensity of today's fishing, and suggests certain modifications of the existing trout regulations.

6. It is suggested that a later opening date and a smaller daily limit would materially assist in improving the fishing and getting more value from the annual trout harvest.

7. The heavy fishing demands that adequate funds be forthcoming to maintain the fishing, and that furthermore every cent should be spent as efficiently as possible.

8. The "test water" program offers a real opportunity to determine what the trout fishing situation is really like. It will help formulate better stocking policies, by revealing the relationship between the number and size of the fish planted and the subsequent catch.

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Discussion

Mr. Markus: I would like to know what bait was used to catch these rainbow trout on that stream.

Dr. Davis: Most of the rainbow trout were taken on flies and not on bait, because the greater part of the bait fishing is done early in the season when the rainbow trout are spawning and not taking at that time either bait or fly. During the first two or three weeks of the season very few rainbow trout are taken at all. Later when the conditions become favorable for fly fishing, it is then that most of the rainbows are taken.

Mr. Markus: What kinds of fly are used?

Dr. Davis: Both wet and dry fly, the wet fly being in the majority.

Mr. Markus: Could you give the names of the flies?

Dr. Davis: The most popular fly is the Gray Hackle. The Stonefly is another very popular fly, and the Coachman also.

Mr. Eschmeyer: Has any attempt been made to express that catch in terms of fish or pounds per acre of water?

Dr. Davis: No attempt has been made in this paper, but of course it can be done. This is merely a preliminary analysis. The season closed on the 14th of August and there has not been time to go more fully into it. We had not accurate data regarding the size of the fish; for one reason, we did not want to bother the fishermen any more than was necessary. We felt that the success of the experiment depended very largely on maintaining the goodwill of the fishermen, and so we simply asked them to report the extreme lengths and the short fish they caught each day, not specifying the weight of each individual fish.

Mr. Markus: I am located in the Finger Lake region in New York State. The Finger lakes have been stocked since 1895 with rainbow trout but we have not been able to catch them. I think it is only a matter of knowing what the proper attachment is to catch these things.

Dr. Hubbs: I would like to ask Dr. Davis if any effort has been made to test the honesty of his Vermont fishermen. I ask the question because we tried out a scheme very much like this on one of our Michigan streams, one of our best areas. The idea was to test the catch on improved versus unimproved sections of the stream. Cables were run across the stream dividing it into sections, and signs were put up asking the fisherman to drop a card in the box saying how many fish he had caught upon the unimproved or the improved section, what kind of fish, and so on. We found that that effort was by no means successful. A very large number of fishermen paid no attention to the request, and a considerable number of the returns, judging from the cards, were either fictitious or facetious; the desires or whims or expectations of the fishermen were sometimes recorded on the cards, rather than the actual catch. Of course, Mr. Lord had there the state law and the prestige of the federal government to induce honesty on the part of the fishermen. But I was wondering if a considerable number of these fishermen either gave false returns or failed to make a return on the assumption that they would not be caught anyway. Was any effort made

on any one day or several days during the season to contact the fishermen as they came out of the area in order to compare their catch with the record that appeared on the cards?

Dr. Davis: Yes, early in the season special men were employed to spend the whole time patrolling the stream for quite a number of days. We feel that the records are quite accurate; we have no reason to believe that the fishermen turned in false reports. During the season the fishermen were cooperating wholeheartedly; they did everything they could to further the purposes of this investigation. We tried to arrange it so that there would be as little trouble to the fisherman as possible; about the only thing he had to do was to get a special permit, issued without cost, and fill in these cards each day. I feel that the results were eminently reliable and constituted an accurate record of the fish caught in the stream during the season.

Dr. Hubbs: It is a splendid thing if you are confident that it is accurate. It is the sort of information we ought to have in a good many streams in a good many states.

STREAM MANAGEMENT IN THE NATIONAL FORESTS

H. S. DAVIS

U. S. Bureau of Fisheries, Washington, D. C.

Although we have heard much in recent years regarding the value of a scientific policy of fisheries management for our lakes and streams, one looks in vain for an instance where such a system has been put into effect over any considerable area. That this should be the case is not surprising when we reflect that until quite recently the average fish culturist, in spite of the labor and tender care lavished on fish in the hatchery, was little interested in the fate of his charges after they left his immediate care. Happily, this attitude on the part of fish culturists is rapidly changing and they now realize that when the fish leave the hatchery their responsibility is by no means ended. This is a logical and necessary development since it is obvious that the welfare of the fish after being liberated in natural waters is fully as important as the efficient operation of our hatcheries. It is evident that no matter how successful our hatchery operations may be, the success or failure of artificial propagation in terms of catchable fish is determined eventually by conditions in the lakes and streams in which they are planted.

In my opinion, no more important step in aquiculture has ever been taken than the agreement recently reached by the U. S. Forest Service and the Bureau of Fisheries providing for the close cooperation of these two bureaus in putting into effect a scientific program of stream management for the waters of the national forests. When we consider that approximately 170,000,000 acres are now included within the boundaries of the national forests and that the area of old forests is rapidly being increased and new forests are being established, the significance of this step is evident. Furthermore, the national forests contain within their borders a large proportion of the game fish waters of the United States and, what is even more important, these waters will not be endangered in the future by agricultural or industrial development.

According to this agreement the Bureau of Fisheries assumes responsibility for conducting research necessary to lay the foundations for fishery management throughout the national forests and will also provide the fish required for stocking forest waters. On the other hand the Forest Service assumes responsibility for the administration and operation of management plans and will also undertake stream and lake improvement and all planting work under instructions and recommendations provided by the Bureau of Fisheries.

The policy of stream management adopted for the national forests can logically be divided into four sub-divisions as follows:

1. An appraisal of physical, chemical, and biologcal conditions in the waters of the national forests and their effects on fish life. This is the primary purpose of stream surveys.
2. Modification of existing conditions where considered advisable so as to make the waters better suited to game fish. This is the purpose of stream and lake improvement.
3. Development of a comprehensive scientific program for rearing and planting fish. Such a program should be designed to utilize the productive capacity of forest waters most efficiently and economically.
4. Regulation of angling in such a manner as to assure the greatest possible benefit from the scientific treatment and stocking of streams.

Stream Surveys

The first step in any program of fishery management is a biological survey to provide an inventory of conditions in each lake and stream which affect the fish population. With this information at hand it is possible to determine to what species of fish each body of water is best adapted and the number it can support most advantageously. This knowledge is essential for the development of a rational and systematic stocking policy which will make possible the most efficient utilization of forest waters. In the absence of such basic information fish are frequently planted in waters to which they are not adapted and in numbers which bear no relation to the productive capacity of the stream. The net result is a great waste of fish and fish food and generally unsatisfactory angling conditions.

Owing to great variations in streams and lakes from year to year and also at different seasons it is obvious that a survey of conditions in a body of water at any one time can give only a very incomplete picture of conditions as a whole. In the case of many streams, as a result of reforestation, stream improvement, and other more or less permanent changes in the watershed, conditions in a very few years may be quite different from those that characterize the stream at present. For these reasons it is planned to repeat the surveys at intervals of a few years in order to obtain a more accurate and complete picture of conditions than can be acquired by a single survey, no matter how thorough and detailed it may be. Furthermore, such successive surveys will furnish valuable information on the effectiveness of measure adopted to improve angling conditions in these waters.

In accordance with this program stream surveys were conducted during the summer of 1934 by four parties operating in national forests in New England and the Appalachian Region, seven parties operating in forests in the Rocky Mountain and Great Basin Region, and three parties operating in California forests. During the present season, owing to lack of funds, it was necessary to discontinue the survey work temporarily but it is hoped that arrangements can be made to carry on extensive surveys next summer.

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Stream Improvement

A carefully developed plan for stream improvement is an important feature of any comprehensive plan of stream management. While it is not believed that stream and lake improvement will accomplish all that is frequently claimed for it, there is no reason to doubt that it will prove a valuable aid in the efficient utilization of forest waters. There are many streams that are more or less deficient in certain factors that are essential for the development and well-being of fish and other aquatic organisms. Although in other respects these streams may afford favorable conditions for fish, it is apparent that the factors in which they are deficient will hold the fish population to unnecessarily low levels. If these limitations can be corrected, even in part, it is evident that the streams will be capable of supporting larger numbers of fish than before.

The majority of the streams in the national forests are in mountainous regions and are consequently subject to sudden and destructive floods which present a difficult problem to stream improvement workers. After a year's experience, however, in which various types of installations have successfully withstood exceptionally high floods we are convinced that structures can be installed that will last for many years but information regarding their ultimate effect on the stream is still very fragmentary. There is no doubt, however, that many improvement devices, if properly constructed, will provide shelter and protection for the fish resulting in their more uniform distribution, but it is still questionable if on the average trout stream any material increase in the food supply can be effected. Improvement work in sluggish streams is in many respects much simpler than in mountain streams and possibly also more effective.

In connection with the surveys, stream improvement work was carried on last summer in most of the localities in which stream surveys were conducted and this work is being continued during the present season. For the most part, the work has been done by CCC labor under the supervision of technically trained men.

Artificial Propagation and Stocking

The success or failure of any policy of stream management will depend very largely on the efficient utilization of the product of the hatcheries. With the rapid increase in fishing intensity in forest waters resulting from better roads and more anglers, more and more streams each year are suffering from overfishing. Since it is the policy of the Forest Service to emphasize the recreational value of the national forests there is every reason to believe that this increase in the number of anglers will be even greater in the future than in the past. Under such conditions it is idle to expect that, in the more accessible waters, natural propagation can be relied upon to maintain the fish population. No matter how favorable conditions for natural propagation may be it is apparent that in heavily fished streams the adult

fish that survive from year to year will be far too few to maintain the stock. This is particularly true of the smaller trout streams which are more easily fished out than larger streams or lakes. Furthermore, it requires a large amount of food to grow fish to catchable size and since there is a limit to the food supply, even in the most productive waters, it is evident that we must resort to artificial aids if we are to provide the angling public with satisfactory sport.

This of course means that in order to realize the greatest benefits from our fishery resources it will be necessary to maintain an extensive system of hatcheries and rearing pools to supply fish for stocking forest waters. Since it would be impracticable to operate a hatchery in each forest, rearing pools to care for local needs will be constructed where suitable sites are available. In most cases these rearing pool units will be of sufficient size to require the entire time of a fish culturist in looking after them. In addition to rearing pools small holding pools will be built at strategic points throughout the forests. These pools are designed to hold fish temporarily until they can be planted in waters in the immediate neighborhood. In this way it will be possible to distribute the fish properly throughout the length of the streams instead of dumping them hurriedly at a few points that happen to be most easily reached.

Regulation of Fishing

With few exceptions, regulation of fishing is a matter for the States on which the forests are located, but it is believed that through cooperation with the States concerned it will be possible to obtain modifications in existing laws which will assist in providing more satisfactory fishing conditions, where it is apparent that such modifications are desirable. It is believed that by proper regulation a great deal can be accomplished to assure fair fishing conditions for anglers throughout the season rather than allow a few fishermen to clean out a stream during the first few days.

Fishery Investigations

An essential part of the stream management program is the provision for experiments and investigations to be conducted by the Bureau of Fisheries, the ultimate aim of which is to provide information that will make it possible to constantly increase the efficiency of the stream management program. In this way mistakes can be rectified and new and better methods developed.

There is still a great deal to be learned in connection with all phases of fishery management; in fact we have as yet made little more than a beginning in this field. To be of value such investigations must be conducted systematically for a number of years and conclusive results cannot be expected immediately. The difficulties involved in such investigations no doubt account for the relatively little progress already made.

The investigations will be concerned with such problems as improvement of survey methods, the development of a better classification of streams and lakes according to their productive capacity, the effects of various environmental factors on food organisms, and the efficiency of natural propagation of game fishes. In connection with the stream and lake improvement work, careful and detailed studies will be made of the effect of these improvements on fish and other aquatic life. These will be broad enough to include studies on the practicability of other methods of improvement as well as those in common use. At present nearly all stream improvement work is designed primarily to provide shelter and little attention has been paid to the possibility of increasing natural food or of aiding fish in other ways. As an aid in the development of better stocking methods a definite stocking policy will be formulated for certain streams and lakes and religiously followed for a number of years. A comparison of the numbers and sizes of fish taken from these waters each year will yield information of great value in enabling us to place our stocking policy on a strictly scientific basis. This list is far from complete and is simply given as an example of the type of studies which it is proposed to undertake.

For various reasons it has been thought best to carry on investigations in several different regions rather than to concentrate the work in one locality. Plans so far developed call for the establishment of experimental streams in national forests in Vermont, Virginia, West Virginia, North Carolina and California. Additional forests will doubtless be added in the near future.

Since by a recent act of the Vermont Legislature the Bureau of Fisheries, in cooperation with the State Department of Fish and Game, is authorized to set aside certain streams as "test" streams for the purpose of determining the number of fish caught during the season, four such streams are planned for the Green Mountain National Forest. Two of these streams are to be stocked heavily with brook trout to determine, if possible, the maximum number of fish which can be produced in streams of this type and the number of fish that should be planted to accomplish this result. Other investigations on these streams will include a study of the effect of stream improvement on both fish and food organisms. The other two streams, which are very similar in every essential respect, will be used to determine the relative value of brook and rainbow trout for stocking intensively fished streams.

In Virginia, several streams in the Natural Bridge Division of the George Washington National Forest have been set aside for studies on the effect of various intensities of stocking on production of both fish and bottom organisms. Experiments will also be conducted to determine the feasibility of increasing the production of natural food in such streams. Since these streams are within the boundary of a newly established game refuge they can be closed to fishing as long as may be considered necessary for the success of the experiments. In

addition to these streams, North River in the Shenandoah Division of the George Washington Forest will be utilized in an attempt to determine the effect of stream improvement on fishing conditions in general.

Since the entire Pisgah Division of the Pisgah National Forest in North Carolina is a game preserve where the streams can be opened or closed to fishing at will, this area will be utilized for a public demonstration of what can be accomplished by scientific fishery management. This forest contains many excellent trout streams which have been extensively improved and it is believed will provide an ideal set-up for an object lesson in fishery management.

In California, two small mountain lakes are being utilized to determine the annual production of waters of this type. One or more experimental streams will also be set aside for intensive study under conditions very different from those found in Eastern waters. These investigations will include a study of the losses occurring among fish of various sizes after planting, and the extent to which natural food can be utilized without danger of encountering the law of diminishing returns. Extensive studies on the steelhead trout are also being conducted in this area, including its life history and the effects of stream obstructions and diversions on migratory fish.

Summary

The U. S. Forest Service and the U. S. Bureau of Fisheries have entered into a cooperative agreement for putting into effect a program of fishery management for the waters of the national forests. This program includes stream surveys, stream improvement, a scientific system of stocking and regulation of fishing so as to assure the public the greatest possible benefits from scientific stream management. Provision is also made for extensive investigations by the Bureau of Fisheries on various problems of stream management.

MEASURING POLLUTION IN FRESH WATER STREAMS

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In measuring stream pollution a normal or a set of standards with which the conditions produced by pollution can be compared is the first requisite. Various attempts have been made to use a single factor as oxygen level in determining the extent of pollution, but such measurements of pollution when applied to fisheries problems are usually unsound biologically because pollution as is well known to the fisheries biologist, may be harmful through specific toxic effects without disturbing the major characteristics of the aquatic environment, or pollution may alter several factors simultaneously as dissolved oxygen, carbonate balance and relative acidity, or the pollutants may be detrimental through combinations of such factors and toxicity as well.

Pollution measurements have also been clouded by the use of averages. Absurd as it may seem to the biologist, the writer in a recent investigation of the pollution of the Mississippi River by garbage from the City of St. Louis, was presented officially with carefully compiled data on dissolved oxygen of the river water and the biochemical oxygen demand of the garbage, which data had been averaged and showed that the average oxygen level throughout the year could be tolerated by fishes, in spite of the fact that at several times during the year it was acknowledged that the dissolved oxygen in the river water after receiving the garbage fell below the critical level for aquatic life. Unfortunately a fish dies only once—and at the time when the oxygen conditions are critical regardless of the average oxygen level for the year. Yet averaged data on relative acidity, sulphite content, biochemical oxygen demand and other effects of pollution are continually submitted as proof that a particular effluent is not producing conditions intolerable for fish life, although included in the data on which these averages are based are extremes of pH, or sulphite content, or some other pollutant condition, which would be lethal for fish life if maintained but a few hours.

The measurement of pollution in rivers and streams is complicated further by the fact that various species of fish and other aquatic animals, and even individuals of the same species but of different ages have different degrees of tolerance to variations in the environment, and to the cumulative effects of many stream pollutants. Consequently the presence or even the survival for a time, of fish in

waters suspected of pollution does not constitute evidence that these waters are either satisfactory or safe for fish.

Therefore in determining limiting values for the various substances in stream waters, with reference to the effects on aquatic life, extensive field studies on both unpolluted and polluted streams throughout the United States, and experimental tests under controlled conditions in both the field and laboratory have been made. From these studies data of three sorts have been correlated, (a) the amounts of these substances found in natural waters where fish were living successfully, (b) the physiological responses of fish and other aquatic animals to variations in the concentrations of these substances, and (c) the survival of aquatic forms when exposed to these substances over long periods under controlled conditions.

Three conclusions stand out conspicuously from the work as completed:

(1) Pollution measurements and determinations of pollution rectification must not be compared with water conditions which are barely sublethal for the adults of some species of fish, even though such water be useable for industry or potable for man, but with water conditions which are favorable to all stages of the desirable food and game fish of the region, and to those aquatic organisms both plant and animal which comprise the food and food chains of these fish. The pollution problem can not be considered as solved in the Mississippi River below St. Louis merely because some fish, chiefly carp and catfish, can tolerate the reduced oxygen level and high ammonia content of the river water resulting from that city's wastes, and are consequently eking out a miserable existence at the mouths of sewers. Nor can industry be absolved from responsibility in the Androscoggin River in Maine, where analyses and surveys have shown that the oxygen content of the water is safe for fish, that the sulphite content is below lethality, and that some fish are actually found in the polluted waters (having come in from side streams), as long as the blanket of fine cellulose pulp which has obliterated the bottom fauna for miles and from which pulp mass volumes of methane and carbon dioxide rise when the layer is disturbed, is ignored.

(2) Pollution measurements of specifically toxic substances must be made with due consideration for conditions in the polluted stream and not arbitrarily from toxicity tables. The chemical and physical conditions of the water receiving the pollutant are particularly significant, as the synergistic and antagonistic relations of other materials in the stream water both suspended and dissolved, may greatly alter the relative toxicity for fish and other aquatic organisms of any given amount of many substances, i.e., the actual amounts of ammonia, copper, arsenic, sulphite and various other elements and compounds which may be harmful to fish and aquatic organisms

vary with the presence or absence of certain other substances in the stream water. There are many demands for arbitrary evaluations for fish, of the toxicity of copper, arsenic, and other pollutants regardless of local conditions. Perhaps these demands are results of the natural tendency to refer back, wherever possible, to human standards. The quantities of various substances fatal or harmful to man can be determined in general within rather narrow limits because these materials are usually taken internally by man with little or no interference due to the environment, although even in man the action of cumulative poisons is not so easily determined. This comparison with toxicity measurements for man is valid in its entirety for fish, only when the toxic material is administered to the fish internally, a condition not readily met in the aquatic environment. Our experiments have shown that catfish will refuse food containing small quantities of dissolved copper salts and will regurgitate solid food in which copper salts have been concealed when these copper compounds begin to diffuse out of the food. These same fish, however, were poisoned easily by direct injection of small quantities of copper compounds into the body cavity, or slowly by keeping the fish in water containing much larger quantities of dissolved copper salts. The problem of absorption by the fish is therefore an important one in pollution studies, and both the condition of the toxic substances and the permeability of the living membranes of the fish to them are strikingly influenced by many chemical and physical factors in the aquatic environment. For example, the toxicity of ammonia for fish and many aquatic animals increases progressively as the water becomes more alkaline or as the amount of carbonate is increased, up to certain limits. This is due in part at least to the high toxicity of ammonium carbonate when ionized as compared with most of the common ammonium salts. Again, copper salts are very toxic in distilled water to many fish, but this toxicity can be greatly reduced by adding small quantities of any of several relatively harmless salts as magnesium sulphate.

(3) *Natural water conditions* favorable or unfavorable to fish and other aquatic life can be ascertained quite satisfactorily in most cases by determining repeatedly at different times of the night and day and at various seasons of the year.

(a) Dissolved oxygen
(b) pH
(c) Ionizable salts
(d) Total ammonia
(e) Total iron
(f) Suspensoids

since these determinations not only give specific data concerning particular conditions, but also concerning several complexes which vary in even unpolluted streams and which are also specifically affected by many forms of pollution. These determinations alone (and others

which may be added as the work progresses) do not suffice for the complete definition of stream water as favorable for aquatic life, but standards of purity from these determinations cover the more basic conditions which must be maintained in any stream if it is to support a prosperous fish fauna, and those conditions on which specific pollution is superimposed.

(a) *Dissolved oxygen.* The oxygen level, i.e., the amount of dissolved oxygen present in the water is influenced by many types of pollution, and is a critical factor because of the need for oxygen in life processes. Consequently dissolved oxygen has figured in most discussions of stream pollution.

From over 5,000 determinations of dissolved oxygen in the waters of various streams throughout the United States and northern Mexico, made at all hours of the night and day, it was found that the mid-summer dissolved oxygen values during periods when the streams were low and the water temperatures high, were consistently above 5 p.p.m. in the cleaner portions of the large rivers at those stations where a good mixed fauna of both fine fish and rough fish were taken, and where there was a good fauna of food organisms. In unpolluted tributaries where good conditions for fish were found the dissolved oxygen was often 6 p.p.m. or higher. At the same time few if any fish (chiefly carp and gar) were taken where the dissolved oxygen was below 4 p.p.m. A dissolved oxygen level of 5 p.p.m. or above was clearly indicated by our field studies as necessary to support a prosperous mixed fauna of warm water fish and their food chains, during the season when the oxygen carrying power of the water was low and the metabolic activity of the fish high, due to the high water temperatures (20-30 degrees C.).

These field observations alone do not suffice to establish conclusively 5 p.p.m as the desirable oxygen level for these fish, as it is well known that certain insect larvae are found in ripples where the oxygen content of the water is high, not because these larvae have a high oxygen demand, but because of certain food conditions which obtain in the ripples. Reviewing the literature on oxygen consumption and the lethal oxygen level for fish one soon is convinced that oxygen can readily be an important factor in the distribution of fish and our field findings are in line with those of other observers if the various conditions are properly evaluated. The acute lethal oxygen level for fish varies with several conditions and with the species, from 0.2 p.p.m to 2 p.p.m or higher. It is well established for man and many other animals that the lethal or asphyxial level of oxygen, and the oxygen level which will barely support life if severe compensations are made, and the level at which respiratory and cardiovascular compensations begin, are three quite different oxygen percentages, and that the latter, i.e., the oxygen level at which respiratory compensation begins, marks the lower limit of the favorable respiratory environment, even though the lethal level is very

much lower. It has been shown for man, normally living in an atmosphere containing 21 per cent oxygen and with an acute oxygen collapse point near 6 per cent oxygen, that the reduction of oxygen to only 16 per cent results in definite respiratory and cardiac compensations.

Applying this same principle to fish a special respiromenter was constructed in our laboratories and it was found that under uniform conditions of water flow, temperature (20-25 degrees C.) and water composition, goldfish, perch, catfish, and other fresh-water species began respiratory compensations both in rate and volume when the oxygen level was reduced to slightly below 5 p.p.m., i.e., the environment became unfavorable to fish. These experiments give a definite physiological background for the differences in fish fauna found during our field work in waters carrying 4 p.p.m or less as compared with those carrying 5 p.p.m. or more dissolved oxygen, and are in accord with the statement of Plehn (1924) that even carp show respiratory difficulties when the dissolved oxygen falls to 4.3 p.p.m.

In view of the data from all sources, 5 p.p.m. dissolved oxygen seems the lowest value in waters in which our warm water fish may be expected to prosper during the summer season. This value, 5 p.p.m., therefore, has been taken as the standard for dissolved oxygen from which deviations due to pollution are measured, particularly since this is the breaking point at which respiratory compensations in these fresh-water fishes begins, and an environment which demands physiological compensations is withdrawing energy and producing strains which sooner or later become physiological liabilities to the animal, even though the individual be able to survive the required compensations. In our pollution studies waters carrying less than 5 p.p.m of dissolved oxygen during the summer have been viewed with suspicion, and these suspicions have been confirmed in most cases.

By similar combinations of our field and laboratory work (Ellis, 1935) waters in which the warm water fishes may be expected to thrive have been defined still farther as having:

(b) relative acidity between pH 6.5 and pH 8.5.

(c) ionizable salts as indicated by a conductivity at 25 degrees C. between 150 and 500 mho $\times$ 10^{-6} and not exceeding 1,000 mho $\times$ 10^{-6}.

(d) total ammonia not exceeding 1.5 p.p.m

(e) total iron not exceeding 50 parts per million.

(f) suspensoids of a hardness of 1 or greater so finely divided that they will pass through a 1,000 mesh screen, and so diluted that the resultant turbidity will not reduce the millionth intensity depth for light penetration to less than 5 meters.

Deviations from these values call for investigations of pollution possibilities and have enabled us to measure both general pollution

and specifically toxic pollution not in terms of barely tolerated sublethal conditions but in terms of a complex in which fish will thrive; for the successful survival of fish, as of any other organisms, calls for conditions which are favorable not merely sublethal. If such favorable conditions for fish are to be maintained and fish and other aquatic organisms are to be protected against the toxic actions of many stream pollutants, all pollutants not readily oxidizable or removable by the stream should be excluded, including particularly all cellulose pulps, wastes carrying heavy metallic ions and gas factory effluents. Other types of wastes should be diluted to concentrations non-toxic to the aquatic life of the particular stream. No substance should be added to stream waters which would cause a deviation in general conditions beyond the limits outlined above.

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FEDERAL AND STATE COOPERATION IN FISHERY INVESTIGATIONS

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To such a body as the American Fisheries Society it is unnecessary for me to justify the conduct of fishery investigations. The need for sound information regarding the life and growth of aquatic animals, their increase or decrease and their migrations and habits is probably nowhere better appreciated than among administrative fishery officers and technicians. To all of you the inadequacy of financial support for work of such vital importance is a painful daily experience; hence it is worth while for us to consider the possibilities of pooling our limited resources in the interest of economy and efficiency. We should discover where the field of work may be divided among the various agencies and plan how we may best proceed in the development of a conservation policy with the view to long time application as well as how the sportsman's license dollars can be spent most effectively to give him an immediate return in better angling.

THE SPHERE OF FEDERAL AND STATE AUTHORITY

The sphere of Federal and state authority in the conservation of wild life is adequately prescribed by law. Based on ancient Roman and old English common law, all animals, *ferae naturae,* as the lawyers say, are the property of the State, title to which resides in the State government until they become private property through reduction to actual possession. In recognition of this principle, all of the states have passed laws regulating the manner in which fishing and hunting shall be conducted, and nearly all of them charge a license fee to their citizens and non-residents for the privilege of taking the common property represented by the fish and game resources. When the Constitution was drawn the control of fish or game was not delegated to the Federal Government and, except for territories which constitute federal domain, strictly speaking, the Congress has no power to legislate with regard to hunting and fishing. Federal control over the marine fisheries under the Maritime laws extends only to American citizens on the high seas and the control of boundary waters is exercised only through the power of the Federal Government to conclude treaties with foreign nations which become the supreme law of the land. It is true that the Federal black bass law is based upon the interstate commerce clause of the Constitution but the Government merely promotes efficient enforcement of state regulations when interstate shipments are involved.

Under the welfare clause of the Constitution, however, the Federal Government is fully justified in carrying out the mandate of Congress to conduct investigations "to determine whether and to what extent the fishery resources have declined, what the cause of the same may be, and what remedial measures may be recommended." The remedies recommended must be applied by the state governments to the waters within their jurisdiction; hence it is that responsibility for fishery conservation is mutually divided between the Federal and state governments. The enforcement of conservation laws is in the main, the responsibility of the states, but acquiring the fundamental and practical knowledge upon which such laws must be based to be effective is equally the responsibility of the Federal and state governments.

Recommendations of the Secretary's Advisory Committee

The fisheries advisory committee of the Secretary of Commerce in its meeting last spring considered the fields of work of the various agencies for the promotion of fishery research and their recommendations in brief were as follows: that the Federal Government should develop fishery research of more fundamental nature that applies to fisheries problems over wide areas or that relate to general principals of conservation without respect to geographical application. Thus the investigation of fisheries problems concerned with high seas fisheries of all coasts and with fisheries in boundary waters are clearly the responsibility of the Federal Government. Examples of this type of work are to be found in the studies of the fluctuations in the yield of the haddock fisheries of the North Atlantic region, the predictions of the magnitude of the runs of mackerel in the middle Atlantic coastal areas and New England; of the causes of the rapid decline of the valuable fisheries of the Great Lakes and of the salmon fisheries of the Puget Sound-Frazier River area.

The Federal Government should also concern itself directly with problems of the fisheries for migratory species common to several states and over which no single state could have complete jurisdiction, such as the shore fisheries of the Middle Atlantic, the shad, crab and lobster of the Atlantic coast, the shrimp of the Gulf coast, and the Great Columbia River salmon fisheries shared by three states.

The Federal Government also should conduct fishery investigations related primarily to stocking the Public Domain, such as the streams and lakes of the national forests. It is directly responsible in regulating the fisheries of Alaska for the conduct of studies necessary to their conservation.

The secretary's Committee recommended that the state governments should concern themselves primarily with research that would improve regulation of the fisheries within their borders, but that the states should cooperate under the direction and guidance of the Fed-

eral Government in the study of problems of the migratory species of the coastal or of interstate boundary waters.

Recent Cooperation in Fishery Investigations

Since its inception, in which this society played a leading part, the Bureau of Fisheries has had valuable cooperation from many sources too numerous to mention in detail. Cooperation in fishery research may be classed under three main types. (1) Direct association of Federal and state investigators united in a common enterprise on a nearly equal basis; (2) cooperation in which the state contributes materially to the support of Federal projects, or, conversely, cooperation in which the Federal Government contributes to the projects sponsored by the states; and (3) indirect or less obvious cooperation involving moral support, encouragement or the furnishing of courtesies and facilities of less tangible nature, or of less monetary value than in the first two types.

As an example of the first category — actual cooperation on a nearly equal basis — I may cite one of the largest projects recently undertaken, the survey of Lake Erie. Under the Bureau's leadership the states of Ohio, Pennsylvania, New York, the Province of Ontario, the Buffalo Museum of Science, the University of Pittsburgh, the Stone Biological Laboratory of the University of Ohio, the University of Michigan and several independent scientific investigators cooperated in a two-year investigation of Lake Erie to discover if possible any factor or factors in the waters of the lake other than simple over-fishing to explain the alarming decrease in the abundance of the most important species of fishes. The Bureau of Fisheries provided the vessel, the States of Ohio and New York financed its operation, the Bureau, the States, the Province and the universities contributed trained personnel. The plan of investigation was sponsored by the Bureau and the work of the various units was supervised by that agency.

Briefly stated, the results of the cooperative effort show that Lake Erie is still richly productive; it was found that pollution of its waters is negligible; that conditions are generally favorable for production of an abundant supply of fish; and the conclusion must be faced that its failure to produce is the simple result of over-fishing. A voluminous report, consisting of several thousand pages of manuscript, still unpublished for the lack of funds, contains a complete account of the hydrography of the lake, the chemistry and physics of its waters, the microscopic plant and animal life contained therein, the larger animals which form fish food, the early development of many species of fish, and the effect of pollution in shore waters. Combined with this survey, the Bureau conducted an independent detailed study of the variations in the fish supply, and the effects of commercial fishing and has offered recommendations to improve conditions in the commercial fisheries.

Another example of fifty-fifty cooperation is the California trout investigation. At the request of the state, the Bureau of Fisheries has undertaken an investigation of the thousands of miles of streams and lakes of the great state of California for the purpose of developing better methods of hatching, rearing and planting trout and managing the supply in order to assure successful fishing. The Bureau supervised this work and contributed two trained investigators; the state matched the Federal budget by providing field expenses and two technical assistants. This work, recently undertaken, promises to be of great benefit throughout the entire state and has resulted in many improvements in stocking practises of long standing.

As an example of the second category of cooperation in which the state or Federal government contributes materially to projects already started by either agency, I may mention the investigation of Lake Michigan. On the completion of the Lake Erie survey, the Bureau undertook the study of the fishery of the next most important of the Great Lakes, and with its own vessel and corps of half a dozen scientists, conducted experimental fishing operations at half a score of stations throughout the lake. Michigan and Wisconsin cooperated directly and most effectively by supporting the Federal Government's study with direct grants of funds amounting to many thousands of dollars. Thus the scope of the investigations was materially increased and many practical problems were solved within the two years that would have remained unanswered had either of the agencies attempted to conduct the work independently. The destructiveness of the deep trap nets and the rapid depletion of the white fish was discovered with the result that Michigan has outlawed this form of gear in her waters. The necessity of protecting the depleted chub fishery by increasing the size of mesh in gill nets was also demonstrated and we have hopes that Wisconsin's plans to improve her laws in this respect will be successful in the near future.

Another illustration of the value of state supported investigation may be found in the oyster study in Puget Sound. For six years the state of Washington has appropriated funds in its annual budget for the support of the field laboratory at Olympia, Washington, to provide facilities for a Bureau investigator in the study of methods of improving oyster farming practise in that region. Discoveries in regard to the time of setting of oysters are guiding the local planters in securing abundant sets of seed, the value of which is highly appreciated by the industry.

The converse of this type of cooperation by the state in Federal investigations is the assistance by the Federal Government in state projects. For many years the Bureau of Fisheries has assisted in a small way in limnological studies by the Wisconsin Natural History and Geological Survey. The Bureau is proud to have contributed even in a modest capacity to the world famous researches of Prof.

Birge and Prof. Juday on problems concerning the biology, chemistry and physics of lake waters that have advanced the world's frontier of knowledge in this direction more rapidly than has been done in any other country. As a part in these studies, the Bureau has assigned investigators to cooperate in studies of the rates of growth of fresh water food fishes in relation to the environment in these lakes that are so well known to these leaders of science.

A still more modest effort at cooperation with the states has been assistance rendered to Connecticut and Massachusetts in tagging trout to study their migration after planting and to determine whether spring planting produces better catches for the angler than fall planting. In the former case the Bureau's investigators analysed the results of the state experiments and in the latter the Bureau investigators conducted the tagging operations.

I have mentioned a few examples of close and effective cooperation. Time will not permit the citation of cooperation of less direct type, involving less financial outlay and sometimes merely the provision of facilities used by our investigators. Many states have provided laboratories or offices for Bureau investigators when engaged in their localities. Again state commissioners have generously placed at the disposal of the Bureau boats, crews and other facilities for surveys and biological investigations. A most recent example of generous cooperation of this sort is that furnished by the state of Connecticut. The state commissioner has placed at the disposal of the Bureau's staff the vessel "Shellfish" for surveys of starfish and other oyter pests to be used throughout Long Island Sound without regard to state boundaries. In recent years, in addition to the cases cited, the states of Maine, Vermont, Rhode Island, New York, New Jersey, Maryland, Virginia, North and South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, Michigan, Minnesota, Missouri, Arkansas, Nebraska, New Mexico, Utah, Montana, Nevada, Idaho, Oregon, Washington and possibly others have offered cooperation of various sorts in scientific fishery investigation.

On the other side of the picture, the Bureau of Fisheries has endeavored to respond to every demand of state officers for assistance in the solving of their problems. Mortalities of fishes at sea or in the hatcheries, have brought requests for study. The Bureau's pathologists are instructed to render aid to the state hatcheries as well as to the Bureau's culturists and, in order to extend this aid as far as possible, the Bureau has instituted a "disease service." State and Federal hatcheries are invited to mail specimens of diseased hatchery fishes to the pathological laboratory whenever an outbreak occurs. The specimens are examined, the disease diagnosed if possible, and recommendations for treatment if known are sent by return mail. Bureau pathologists themselves, like the country doctor, are on call twenty-four hours a day to assist in an emergency of this nature, and they will respond within the limits of our financial resources by

making personal examinations of conditions when hatchery epidemics are reported.

Future Cooperation

Gratifying as the record of past cooperation has been there are many opportunities for increasing the effectiveness of joint efforts in scientific fishery investigations in the future. We are all of us impatient of the snail-like pace of scientific advancement. The poet's lament that "Art is long and time is fleeting" applies even more aptly to accomplishments in research. The investigator does not stumble upon "discoveries." He is robbed of the explorer's thrill of viewing untrod lands from the mountain's crest. His discoveries, dimly foreseen, are literally ground out by days and months and years of arduous labor at sea with nets, and in the laboratory on the adding machine, over the microscope and with the test tube. It is the business of our fishery administrators, therefore, to facilitate his labors in finding better means of conserving our natural resources. Without such constructive work we must content ourselves with obsolete rule-of-thumb methods, and enure ourselves to watching our white fish, our lobsters, our salmon and our chubs go the way of the sturgeon and the buffalo.

The first thing to do is to provide more fishery scientists and put them to work. Every coastal state has sufficiently important marine resources to fully warrant the employment of at least one scientifically trained technician. Every coastal state has sufficiently numerous and immediately pressing problems which the elected or appointed administrators cannot and should not be expected to solve to keep investigators busy for many years. And after the pressing questions affecting wise administration are answered they must then continue a vigilant scientific watchfulness of the varying condition of the resource to assure its perpetuation for future generations.

In this work the Bureau can and should cooperate but the cooperation should be mutual to be most effective. The Bureau's personnel is too limited to give adequate attention to the more local problems, but if these are handled by the state's biologist the Bureau can aid in coordinating and supporting his efforts.

I stress the need of the coastal states of continuous technical assistance. Probably the need of interior states for such assistance is just as great. If circumstances prevent the employment of a competent state biologist, then the next best way is to organize and support cooperative fishery investigations employing Bureau scientists. We plan to continue the establishment of regional biological units, as rapidly as possible. If pending appropriations are made we shall station a skilled aquatic biologist in each of the nine National Forest regions, not only to conduct original studies of stocking needs and methods and to supervise stream surveys and stream improve-

ment, but to aid in coordinating, according to a rational predetermined plan, the stocking programs of the State Fish and Game Commissions, the U. S. Forest Service, the U. S. Bureau of Fisheries and other governmental or private organizations. The states may avail themselves of the aid of these trained men as far as physical and financial limitations permit; and by providing travel expense, physical equipment and supporting assistance, the states may effectively cooperate and thus greatly extend the usefulness of these regional biologists.

I am sure that by pooling resources, coordinating activities, and dividing the field of work under experienced and intelligent supervision we shall succeed in our cooperative efforts to conserve our fishery resources and yet enjoy them to their fullest.

MICHIGAN'S BEAVER-TROUT MANAGEMENT PROGRAM

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Since the first penetration of the white man to this part of the American Continent, beaver and fish have played an important part in the settlement and economic development of the region. Long continued exploitation by fur traders and trappers brought about a decline in beaver population and range, accentuated by the high price levels during and immediately following the world war. In 1920 it was found necessary to impose an extended closed season on all beaver trapping in Michigan, to preserve the few beavers still remaining in remote or sparsely settled areas.

Public sentiment supported the closed seasons at this time and the animals rapidly increased both as to numbers and extent of range. Beaver ranches were established, and many land owners requested that beavers be released on their property.

Nuisance beaver complaints, including the flooding of highways, railroads, pastures, and timber lands; the blocking of culverts and drainage ditches, and the cutting of shade trees around resorts, increased in proportion to the increase in beaver numbers and range. The problem of relief for these damage complaints grew more and more difficult. During recent years the list of complainants was augmented by another vociferous group—the trout fishermen. While all fishermen did not agree as to the benefit or harm done to trout fishing by beaver, the group opposed to beaver continued to gain support. This led to an unsatisfactory condition in certain areas where beaver poaching was tolerated if not actually encouraged.

To safeguard the gains made by the beaver during these recent years and to preserve the trout fishing which has increased in economic importance, especially to those sparsely settled areas having little or no other income and where beaver have again become established or increased in numbers, a beaver-trout managemnt program was deemed necessary.

In order to obtain facts on which such a program could be established, an investigation was started in 1933 by the Department through the Institute for Fisheries Research. Mr. J. Clark Salyer of the Institute Staff was assigned to the work which was continued through 1934 when he resigned to accept an appointment with the U. S. Bureau of Biological Survey. Many of you are undoubtedly familiar with his report and recommendation which was published in the January-February, 1935, issue of *American Game*.

Since the situation in Michigan had become a crucial one, at least in the eyes of many trout fishermen, it was decided to adopt certain emergency measures to lessen the tension and to work out a definite policy of control for the future.

For several years past having conducted studies of beaver abundance and their life histories in cooperation with the Department of Conservation and Michigan State College, I was appointed as supervisor of the beaver-trout management program early in 1935, to inaugurate relief and corrective measures and to continue investigation of the various angles of this problem. Mr. J. W. Leonard of the Institute for Fisheries Research also was assigned to assist in this work, particularly that phase having to do with effect of beaver dams and their removal on trout food organisms.

Mr. Salyer had found that in general the effect of beaver dams in Michigan streams was to create favorable conditions for trout during the first two years, followed by a rather rapid change to unfavorable conditions during the next two years, often resulting in an almost total disappearance of trout after the fourth year. Exceptions to this general situation are, however, both numerous and important.

Mr. Salyer's report indicated that the problem was not really one of beaver versus trout, but rather one of the proper control of beaver on trout streams. The beaver is an animal of great scientific, commercial, and historic interest, and its extermination would be indeed a calamity. Beaver ponds are excellent breeding grounds for ducks, muskrats, and various kinds of aquatic life. A beaver pond without one or more pairs of nesting black ducks is the exception rather than the rule in Michigan. Thus the objective of a beaver-trout management plan should be the maintenance of as high a beaver population as possible without serious interference with trout fishing, or with other forms of wild life. The human factors involved are discussed later in this paper.

The first emergency measure adopted was the opening of the beaver trapping season for fifteen days in the fall of 1934, followed by a fifteen-day open season in the spring of 1935. This drastic measure was deemed necessary to reduce the beaver population before inaugurating a system of control. Whether or not this measure overshot the mark is difficult to determine as yet. Possibly it did so in the upper peninsula, where there is a strong sentiment toward a closed season for 1936.

The second emergency measure adopted was an extensive program of dam removal carried on by conservation officers with the aid of fire wardens and by crews from the C.C.C. camps where available, under the direction of their stream improvement technicians. Here again the method of procedure was a somewhat drastic one. Mr. Salyer had advised that only those dams be removed which were four or more years old, or those which had been abandoned by the beavers, as these two types were most harmful in their effects on fish life. Following my appointment as supervisor of the beaver-trout management program, however, I directed that *all* beaver dams be removed from trout streams, unless some specific objection arose,

in which case removal should await my personal investigation. It would have been impossible to have determined the age, status and condition of occupancy of the thousands of beaver dams on Michigan trout streams in time to permit extensive removal work during the spring of 1935. Then, too, the removal of dams is not a matter of serious consequence to beaver. The washing away of dams is a frequent occurrence during spring floods, and these are soon rebuilt or new ones constructed. Thus the wholesale removal of beaver dams on trout streams served to flush out the streams, and gave us a chance to estimate the remaining beaver population by observing the rebuilt dams, without harmful effects to the beaver themselves.

Various minor difficulties arose in connection with the dam removal program. Mr. Salyer had advised the use of dynamite in dam removal work. This met with a storm of protest from fishermen and others, who feared that the dynamite would kill fish, or permit the silt and debris above the dams to rush down stream in such quantity as to smother fish and aquatic invertebrate life. In consequence of these protests the use of dynamite was generally avoided, pending the results of further investigation. Although Mr. Leonard has not as yet completed his work, he has authorized the following statement: "During the beaver dam removal program of the spring of 1935 especial attention was given to the fate of trout food organisms. In the case of dams removed by hand, bottom sampling tests and direct observation failed to reveal any mortality or loss of insect larvae or other invertebrates in the stream bed proper, either from increased flow or from silt deposition. There was, however, a heavy loss in the former pond bottom, where the organisms were unable to follow the receding water with sufficient speed, and succumbed to the effects of desiccation."

Certain private land owners objected to the removal of dams on streams flowing through their property. Since such objections were comparatively few, these dams were left undisturbed. However, as a matter of policy, an opinion was obtained from the State Attorney General to the effect that beaver dams constitute obstructions to fish migration, and hence come under the laws regarding such obstructions. In case of necessity, the land owner could be compelled to permit the removal of the dam or else construct a suitable legal chute for fish migration. It has not as yet been necessary to proceed according to this ruling.

In a few instances fishermen complained that small trout were being trapped in isolated pools as the water receded from lowered beaver ponds. To avoid this possibility it became the rule to assign one or two members of the dam removal crews to watch for such occurrences, and rescue the imprisoned fish. Actually very few trout were found trapped in this way.

Although complete figures are not at hand, and some dam removal work is still in progress, the number of dams removed in Michigan

numbers over 4,000. The majority of these are listed as abandoned dams, and represent the accumulation of past years during which the beavers were trapped and removed, leaving behind their dams and ponds to become nuisances. With this mass of old dams removed, the future dam removal program will be much less arduous.

Fortunately, the trout season just past was in general more successful than the previous one. This probably forestalled much criticism of our program. Whether or not the dam removal work really had much to do with the improved catches during the season, we were able to carry on our program without serious public criticism.

Having reduced the beaver population and the number of dams by our emergency program, we are now undertaking to plan a regular program for the future. Wherever and whenever the beaver population warrants, we plan to allow trapping during a regular season. Dam removal on trout streams will be carried on following the open season. This work will be under the general supervision of the local conservation officers. The officers are familiar with local conditions, and must bear the brunt of public approval or disapproval, while the C.C.C. men are "here today and there tomorrow," and hence are less directly concerned with the results of the work. The conservation officers will also be required to submit maps showing the location of beaver dams in their districts each winter. These maps will then be used as the basis for the dam removal program.

To protect the beaver from danger of extermination, a series of "beaver refuges" is contemplated. During the summer I have selected various streams in each conservation district, after consultation with local officers, which may be closed to beaver trapping. It is expected that these streams will afford breeding grounds from which the beavers will spread into adjoining waters. The surplus which spreads in this way will then be subject to removal by trappers during the open season. The closed streams have been selected to avoid injurious effects on trout, and the possibility of nuisance complaints, as well as for convenience in law enforcement. Some are rivers which beaver cannot dam. Others are non-trout streams or lakes.

Research work on both beaver and trout will be extended, with the expectation that the results will continually modify our methods of administration.

Were this strictly a scientific report I should close here, with the program outlined in a simple orderly way. Unfortunately, the actual administration of the program involves other important factors. Northern Michigan, including the beaver-trout areas of both peninsulas, is still somewhat in the pioneer stage of thought toward animal conservation. This is peculiarly true of the beaver situation. The conservation officer is even yet regarded by some hunters and trappers as a representative of alien interest determined to prevent

the "poor man" from shooting and trapping his "own" game and fur. Often friendly with the officer personally, the trapper nevertheless looks at violations of the beaver laws as a "game," with himself on one side and the officer on the other. Each brags about how he outwitted the other. The local justices of the peace sometimes enter into the spirit of the game, and fine an apprehended violator as little as is legally possible, so that he can resume his game with the officer without undue handicap.

This sort of thing, while interesting and amusing, is not conducive to the carrying out of "planned" programs. A closed stream in certain parts of Michigan is merely an open challenge to the "game" of violations. Therefore each stream recommended for closing to beaver trapping has been considered from a human as well as from a theoretical biological standpoint. In some districts no closed stream has been designated because of enforcement difficulties. Beaver trappers are clever and persistent, and one hundred per cent enforcement of closing restrictions cannot be expected.

Permanent success for our beaver-trout management program must depend upon a correct appraisal of human psychological principles, and must include an educational program to raise the level of public thinking along the lines of modern conservation ideals.

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AMERICANIZED BROWN TROUT RETAIN EUROPEAN CHARACTERISTICS

HENRY C. MARKUS

United States Bureau of Fisheries, Rochester, New York

R. B. Marston (1895:143), an eminent English sports writer, referring to the brown trout, recorded the following statement, "What our trout may develop into after becoming a naturalized American citizen, time alone can prove." He further states (1895:143) "Given fairly pure running water and our trout do well anywhere if they have a good supply of food. Although varying in color and marking, wherever he is found, *S. fario,* in good condition, is as handsome, as game, and as good a fish in every way as an angler could wish to catch. That is why so many thousands of our best anglers wish to catch him, and why he is so difficult to catch. And it is this very difficulty which places the trout so high in our esteem. Our trout are so well educated that the angler who can with the fly kill a few brace of them in a day must be a good hand."

To determine if the brown trout still retained these characteristics, the U. S. Bureau of Fisheries in cooperation with the Monroe County Park Commission planted 2,700 ten inch brown trout (*Salmo fario*) in Irondequoit Creek in Monroe County, New York, April 26, 1935. These fish were liberated in the stream within the Powder Mills Park area. The length of the stream within the park is approximately two and one-half miles. The stream is an excellent brown trout stream and is so designated by the New York State Conservation Department. The fishing on the stream within the park was opened May 1. Daily permits were issued by the county to the sportsmen who fished within the park. A copy of the permit is here presented.

MONROE COUNTY PARK COMMISSION

POWDER MILLS PARK No. 79

Fishing Permit

____________________ of ____________________

____

is hereby granted permission to take fish in accordance with established rules and regulations of the Monroe County Park Commission. This permit is good only for date entered below and in consideration of payment of the sum of twenty-five cents to the Monroe County Park Commission.

This permit applies only to that part of Irondequoit Creek within the limits of Powder Mills Park.

MONROE COUNTY PARK COMMISSION

Date ______________ Per ______________________________

I agree to observe rules as printed in this permit.

______________________________Applicant

New York State Hunting and Fishing License No. ________

See other side for rules and regulations.

RULES AND REGULATIONS

1. No live bait may be used.
2. Only artificial lures or flies may be used.
3. Tackle must be of fly rod type.
4. Only daylight fishing is permitted.
5. No fish under eight inches in length may be killed or taken to keep.
6. Fish under eight inches must be returned to stream without injury.
7. Not more than eight fish and not to exceed five pounds total weight may be killed or taken.
8. Holder of this permit must show his catch to park foreman and return this permit before leaving the park.
9. New York State Game laws must be obeyed.

Failure to observe these rules and regulations shall be a misdemeanor punishable by law.

MONROE COUNTY PARK COMMISSION

A duplicate copy was made of each permit issued and retained at the office. A nominal fee was charged for each permit to help defray the expense of employing the patrolman, who was on duty from sunrise till sunset. The sportsman was required to display his catch of fish with the return of the permit at the end of the day or when he saw fit to stop fishing. I must say the sportsmen certainly cooperated in this experiment.

The fish were reared by the regular routine hatchery method, except that after the fishing had attained the length of six inches they were transferred to a pond on the hatchery ground with a surface area of approximately one-half acre. A model K electracide with a special transformer of 4,000 volts and two milliamperes was suspended over the center of the pond. The amperage was cut down from the standard models so that the high voltage stunned and did not burn the insects that came in contact with the screen. The electracide contained a seventy-five watt light to attract the night flying insects. It was turned on at dusk and turned off just before the fish culturist went to bed. The primary function of the electracide was to stun the insects so that they would fall on the surface of the water and acquaint the fish with natural food. In addition, it supplemented the regular hatchery food supply. The cost of operating the electracide was approximately $0.006 per hour with an electric rate of seven cents per K. W. H.

During the period from May first to July first 470 daily fishing permits were issued. In other words 470 attempts were made to catch

the 2,700 ten-inch brown trout liberated. The 470 permits were issued to 311 different anglers. 185 fish of the 2,700 liberated were taken in the 470 attempts. Five anglers caught 100 of the 185 trout taken. On the opening day, May first, forty sportsmen were on the stream in the park and took four fish.

It is certain that all of the 2,700 trout did not stay in the two and one-half miles stocked. Some of the fish were taken approximately five miles down and two miles up stream from the area stocked by the author and sportsmen who cooperated in the experiment. These were caught early in July soon after the experiment closed. However, at this date there were plenty of brown trout left in the area within the park. The first week in July another planting of 3,800 ten-inch brown trout was made in Irondequoit Creek.

After the opening day plenty of comment and explanations were given by the unsuccessful sportsmen as to why they could not catch the fish. Upon examination of some of the tackle used by the fishermen on the opening day two of them had nothing but big red flies. The author had good luck in catching the trout by imitating the tent caterpillar during the tent caterpillar season and so did some of the successful sportsmen. Tent caterpillars were very abundant in Monroe County the latter part of May and the first part of June. This was the only tackle observed by the author that was successful other than the ordinary brown trout tackle used in season.

The result of an average group of anglers taking such a small percentage of the fish liberated seems evident that brown trout even though they are grown to a length of ten or twelve inches in hatcheries soon gain their natural characteristics when liberated in the streams.

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WHEN DO PIKE SHED THEIR TEETH?

Milton B. Trautman and Carl L. Hubbs
Institute for Fisheries Research, Ann Arbor, Michigan

> *From the days of Gesner downwards, more lies—to put it in very plain language—have been told about the pike than any other fish in the world; and the greater the improbability of the story, the more particularly is it sure to be quoted.*
>
> —Frank Buckland, 1880.

The pike which reached the venerable age of 260 odd years; the one that grew to the amazing length of 19 feet and weight of 350 pounds (something must be wrong about those figures, for according to the normal length-weight relationship a 19-foot pike should weigh about a ton and a half); the pike which was found to "have an infant child in its stomach"; the one that nearly severed a hand from an unsuspecting boy swimming in a stream; another one that, going to the other extremity, "was known to have seized the foot of a young woman while she held it naked in a pond:" such pike, referred to by the famous British fish conservationist "in very plain language," fortunately have died, or been forgotten; or have failed to swim from their European haunts across the ocean to America.

The pike on our side of the Atlantic, although usually classed in the same species, are seldom thought to attain such age or appetite. In fact our pike are claimed to lose their appetite in the heat of summer, at just the season when they should be feeding most heavily and growing fast. At least that is the theory on which most pike fishermen rely, to explain why they fail to catch pike in late summer. We suspect that guides, finding it an excellent alibi to satisfy their unsuccessful customers, have been to a large degree responsible for keeping this idea alive.

The reason almost always given for the seasonal loss of appetite suffered by our northern pike, and likewise by our muskellunge and chain pickerel, is that the fish after shedding its old teeth in late summer, grows a new set. The pike when cutting teeth, like a human infant in the same predicament, is assumed to develop sore gums, so sore in fact that he refuses to feed.

Referring to the muskellunge, concerning which the tooth-shedding and sore-gum theory is perhaps even more widely current than for the northern pike, the well-known angling author Dixie Carroll wrote:

> About the middle of August the musky loses his teeth and his mouth is in such shape that it takes something mighty aggravating to arouse enough anger to make him forget his sore molars [*sic*] and strike . . . . September

tenth of last season I examined three musky caught on that day, and in the mouth of each was a new set of sharp-edged teeth, firmly set, while, hanging loose in the back, were still the remains of the old teeth, which had not entirely parted company with their owners.

To test the idea that members of the pike family shed their teeth at a particular season, and to determine in what manner the teeth are shed and replaced, we have examined and tabulated the teeth of 188 northern pike (*Esox lucius*), 7 muskellunge (*Esox masquinongy masquinongy* and *E. m. immaculatus*) and 6 chain pickerel (*Esox niger*). With only 6 exceptions all the specimens used are more than 300 mm. (about 1 foot) in standard length, from tip of snout to base of caudal fin. These fish were collected in every month of the year excepting February and December. Adequate numbers of northern pike were examined for each month from April to September inclusive.

The teeth of the pike that are involved in the sore-gum theory are the huge knife-like, compressed canines which line the hinder two-thirds of the side of each lower jaw. The teeth in the front third of the lower jaw are round in section, hooked, much smaller, and seldom missing at any time. Those near the symphysis (extreme front) of the lower jaw are semi-depressible, while those farther back grade into the large canines which were counted. In counting the canine teeth, however, it was possible to differentiate between these and the smaller anterior teeth, with little obvious error.

The teeth of the upper jaw, borne only on the premaxillaries, which form the edge of the front third of each jaw, are in one row, relatively minute and seldom missing.

The hinged, depressible teeth, with which the roof of the mouth bristles, become enlarged toward the inner edges of the long palatines and on the broad head of the vomer, are almost shagreen-like on the posterior part of the vomer, as also on the opposing midsection of the tongue; whether large or small, these teeth on the roof of the mouth and on the tongue are always present in great numbers, showing no very obvious or extensive shedding or renewal at any time.

The canines of the lower jaw, in contrast, are very obviously subject to loss and renewal. Not one of the more than 200 specimens examined had as many as three-fourths of its full complement of these large teeth in service; few had as many as two-thirds in use; but all had a number in use. The method of replacement is somewhat like that of the rattlesnake's fang or the sting-ray's spine, multiplied by about 16 times on each lower jaw. The wide strip of gum covering the hinder two-thirds of each lower jaw is divided internally by walls, of connective tissue, into about 16 sections which extend inward and backward from the outer edge of the jaw. Along the middle of each division one finds on dissection a single, even file of teeth in graded series of development. The innermost of these teeth is often merely a sharp little tip; the outermost is either a tooth in service or one being prepared to take the place of one that has been lost or shed.

If a tooth in service has been broken off, its very widely flaring bony base is resorbed, as is a loose piece of bone in a human gum. This process continues until the base is completely removed, leaving bare a square section of the flat surface of the mandible. The lower end of the replacing tooth then moves into position; a new, flaring, flat-bottomed base is then formed to fit the square space on the jaw bone, as soft tissue which later ossifies and becomes very firmly attached to the plane surface of the jaw. As the base enlarges it becomes united also with the inner edge of the thin, upturned edge of the mandible, and is separated from the base of the fixed tooth on either side only by connective tissue walls which bound its section of the gum. Filling the entire tooth-supporting section of its compartment, the base thus becomes square. During this final stage in the replacement process, the needle-like tip of the new tooth moves outward until it lies along the outer edge of the gum, almost but not quite vertically over the hardening base. As it moves outward, the extreme tip becomes exposed above the gum, and the whole outer side of the tooth comes to lie against the lower lip. As a result of these simultaneous modifications at the base and tip, the new tooth is brought into service. Its tip is as sharp as a needle; its front and rear edges are expanded into knife-like keels.

The replacement of the teeth proceeds in such a manner, that those in service are usually scattered along the whole portion of the jaw bearing these enlarged teeth. The pike therefore, barring rare accidents, retain at all times an efficient dentary equipment. The first tooth of the series counted is usually small and fixed, that is, in service. Then follows another small tooth, or 2 or 3 increasing in size, usually in process of replacement (not fixed to jaw). Behind these are usually 2 very long piercing teeth, corresponding in position and function to the canines of a carnivorous mammal; one of these super-canines is almost always in service; one is usually being replaced. Of the 8 to 12 most posterior teeth, which gradually decrease in height so as to form a rather even, gently ascending edge, several are usually being replaced. The last 2 or 3 very small teeth, located behind the corner of the gape and therefore protected, are usually fixed to the jaw.

It is not evident whether old teeth are shed and replaced, except when broken. In any event the replacement process assures an equipment of sharp teeth throughout life. The larger adults examined seem to have more broken teeth than the smaller ones, suggesting a slower rate of replacement as compared with the rate of loss.

We find little or no evidence that the number of canine teeth increases with age. As the jaw grows longer, each tooth section becomes proportionately larger, so that a three-foot pike has no more canine teeth than a five-inch pike. Accurate counts of these teeth, made with the aid of dissection in order to avoid overlooking any teeth in the early stages of replacement or any small ones at the pos-

terior end of the jaw, are listed in Table 1. The average number of canines per jaw in 5 specimens 104 to 265 mm. in standard length (roughly 5 to 12 inches long over all), is 15.8; the average number of teeth in 10 pike 315 to 960 mm. long without caudal fin (about 14 to 42 inches over all), is 15.9.

TABLE 1. ACCURATE COUNTS OF CANINE TEETH, INCLUDING THOSE BEING REPLACED ON EACH LOWER JAW OF NORTHERN PIKE OF DIFFERENT SIZES

Standard length	Number of canine teeth: Left jaw	Right jaw
104	15	12
130	17	15
151	15	16
255	18	17
265	16	17
315	17	18
315	18	15
320	15	15
430	14	15
460	16	16
500	15	13
580	15	15
600	18	16
675	18	16
960	17	17

Counts of the canine teeth in 178 adult pike, made without dissection, likewise show no increase in number in the larger fish (Table 2). These counts are consistently about 4 too low: it was virtually impossible, without dissection, to perceive all the teeth in early stages of replacement or the one or two very small through usually fixed teeth on the edge of the jaw behind the angle of the gape.

TABLE 2. COUNTS OF THE CANINE TEETH ON EACH LOWER JAW IN 178 ADULT NORTHERN PIKE OF DIFFERENT SIZES

Size group (Standard length in mm.)	300-349	350-399	400-499	450-499	500-549	550-599	All sizes
No. of fish examined	68	42	30	22	12	4	178
Ave. No. of teeth in service	6.8	6.9	6.8	6.9	6.7	5.9	6.8
Average total No. of teeth	11.7	11.8	11.8	12.4	12.4	10.6	11.9

Since the number of teeth in half-grown and adult northern pike does not materially change with age, it is legitimate to include pike of all sizes in the study made to determine whether the teeth are usually shed or replaced at any particular season. The data bearing on this point are given in Table 2. Every indication, including the evidence shown in Table 2, points to the conclusion that the counts consistently omitted about 4 teeth.

It is evident from the data summarized in Table 3, that the Northern Pike shows no seasonal variation of importance in the number of teeth in service or in the number being replaced. We therefore find no confirmation for the popular idea that the pike shed their teeth exclusively or chiefly in late summer. At all times of the year there is an effective complement of teeth, and at all seasons approximately the same number of teeth are being replaced. Therefore if the rate of replacement is accelerated at any season of the year, the rate of loss must be accelerated to approximately the same degree.

Much less material of the muskellunge and the chain pickerel is

Fig. 1.—Head of a northern pike, *Esox lucius*, showing the bands of teeth (two palatines and one vomerine), on the roof of the mouth, and the one row of canine teeth on the posterior two-thirds of the right mandible.

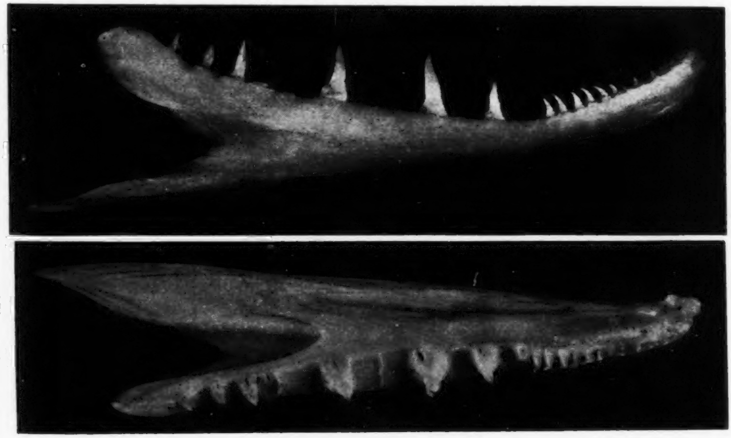

Fig. 2.—A. Outer face of the right mandible (lower jaw) of a northern pike, showing the service teeth in position. B. Inner view of the right mandible showing teeth in service and gaps where teeth are being replaced.

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available, to determine when these species shed their teeth. The few counts made, however, confirm the conclusions drawn from the study of the northern pike (see Table 4). It is probably that all species of the pike genus *Esox* agree in the following respects:

TABLE 3. COUNTS OF THE CANINE TEETH ON EACH LOWER JAW IN 183 ADULT NORTHERN PIKE 300 TO 960 MM. LONG (STANDARD LENGTH) TAKEN IN DIFFERENT MONTHS

	J	F	M	A	M	J	J	A	S	O	N	D
No. of fish examined	2	–	1	20	21	17	30	40	45	7	–	–
Av. No. teeth in service	(5.75)	–	(9.5)	6.4	6.8	7.0	6.8	7.25	7.0	6.5	–	–
Av. No. of teeth being replaced	(3.5)	–	(3.0)	4.9	4.9	4.6	5.6	4.9	4.9	4.9	–	–
Av. total No. of teeth	(9.25)		(12.5)	11.3	11.7	11.6	12.3	12.2	11.9	11.4	–	–

TABLE 4. ACCURATE COUNTS (MADE WITH DISSECTION) OF THE CANINE TEETH ON EACH LOWER JAW OF 5 MUSKELLUNGE AND 4 CHAIN PICKEREL, OF DIFFERENT SIZES, TAKEN IN DIFFERENT MONTHS

Species	Date of capture	Standard length, mm.	Number of teeth: In service	Being replaced	Total
Muskellunge (Wisc.)	July 10	340	6-6	8-9	14-15
Muskellunge (Wisc.)	July 28	475	6-7	9-9	15-16
Muskellunge (Wisc.)	Sept. 14	310	7-6	11-11	18-17
Muskellunge (L. Erie)	Sept. 23	585	10-9	8-9	18-18
Muskellunge (L. Erie)	Nov. 29	438	6-7	9-10	15-17
Chain Pickerel	Aug. 4-5	380	6-6	9-10	15-16
Chain Pickerel	Aug. 4-5	395	7-7	11-9	18-16
Chain Pickerel	Aug. 20	345	7-8	11-9	18-17
Chain Pickerel	Sept. 12	280	8-5	9-12	17-17

TABLE 5. CATCH PER HOUR OF NORTHERN PIKE IN HOUGHTON LAKE, MICH.

	1928	1929	1930	1931	1932
Number of hours of fishing reported:					
May-June	5,102.5	7,144.25	4,895.5	3,184.75	3,080.5
July-Sept.	4,969.0	4,373.25	6,110.75	1,274.5	1,805.0
Catch of northern pike per hour:					
May-June	0.22	0.22	0.22	0.15	0.26
July-Sept.	0.10	0.15	0.10	0.04	0.10

1. The number of canine teeth on the lower jaw is constant throughout life, averaging about 16 per jaw.
2. These teeth are confined in sections of the gum.
3. The canines are much subject to loss and to replacement by accessory teeth being developed in each section of the gum.
4. An effective number of teeth remain in service at all seasons.
5. There is no evident seasonal change of consequence in the number of teeth in service, or being replaced.

Therefore if pike, muskellunge and pickerel can not be caught so readily in the heat of summer as in the cooler seasons, it is presumably not because the fish have just shed their teeth. The Michigan creel census, by such data as that shown in Table 5, has confirmed the general opinion that the catch of northern pike per hour does fall off very notably in the summer.

It is not evident why the catch of the northern pike and its relatives falls off in mid-summer. We find no good evidence that these fish "go off their feed" at that season, although Alfred C. Weed in his Field Museum publication, *Pike, Pickerel and Muskalonge,* states an aquarium muskellunge in Chicago "has been in the habit of fasting for sev-

eral weeks each summer." We do find evidence, by examining the stomachs of about 100 northern pike, that this species at least partakes freely of food throughout the summer: our specimens caught in July and August contain approximately as much food as those captured in cooler months.

We also fail to confirm the popular supposition that "sore gums" are developed in summer (to explain the loss of appetite and the falling off of the catch), although we have not excluded that possibility. The gums of all preserved pike, muskellunge and pickerel examined appeared normal, showing no evidence of inflammation in life. Four northern pike and two mud pickerel (*Esox vermiculatus*), taken in late August and early September of this year, when examined immediately after their removal from the water, showed no swelling, reddening or other pathological symptoms of inflamed gums. Soon afterward, however, sections of the gums reddened, on account of the accumulation of blood in the finer blood vessels, some of which ruptured to produce internal and even external hemorrhages. The same congestion and rupturing of the blood vessels, as is generally known, likewise occurs on the vertical fins, which however have never been accused of soreness. These hemorrhages on the gums and fins are apparently due to the death struggles of the fish, and are naturally most evident where the parts have been bruised, for instance where the gums have rubbed against a hook, plug or spoon. The gums redden chiefly where a canine tooth is being replaced, because the soft flesh is there unprotected by a fixed, external tooth, and is well supplied with blood vessels which nourish the growing tooth. This is apparently the reason why fishermen believe that the gums are sore about the new teeth, or about the old teeth if they mistake a replacement tooth for an old, broken tooth. Whether the blood vessels rupture as readily as in winter has not been ascertained.

The failure to catch pike, muskellunge and pickerel in large numbers in summer may be due to the especial abundance or availability of natural food in summer, or to the retirement of these cold-water fish to deep water at that season, or to sluggishness induced by the warm water.

FISHERIES INVESTIGATIONS IN NORTHEAST BRAZIL

RODOLPHO VON IHERING and STILLMAN WRIGHT
Commissao Technica de Piscicultura, Fortaleza, Ceara

The Commissao Technica de Piscicultura do Nordeste, the purpose of which is to improve the fisheries in the assudes (artificial lakes) of the semi-arid region of Northeast Brazil, began its work in March, 1933. For a better understanding of its programme of investigation, let us present a sketch of the more characteristic features of this little-known region.

The coastal belt, in general, has adequate rainfall, and the east coast, with abundant rain and fertile soil, is covered by tropical forest. The interior, with exception of a few isolated areas of higher elevation, is semi-arid, with predominance of cactus and other spinous plants. There are well-marked wet and dry seasons. In duration and time of occurrence these vary from place to place, but in general the rains come during the period from February to June, and usually in a few heavy rains, rather than in many light ones. In the years of good rainfall, the interior produces much cotton, and cattle raising is profitable. In some years, and sometimes for three consecutive years, the rains are inadequate or fail entirely.

Memorable are the great droughts of 1877-79, 1888-89, 1915, and 1930-32. In such droughts the more prosperous farmers become impoverished, and thousands of people die as a result of famine and disease which accompany the lack of water and absence of proper hygiene. But two or three years of good rain are sufficient to compen sate for the economic loss of a drought.

In 1909 the federal government created the Inspetoria Federal de Obras Contra as Seccas for the purpose of constructing assudes for irrigation, and good roads for the egress of people in time of need. In spite of interruptions in this programme, there have been finished 120 assudes, with a total capacity of 2,120,000,000 cubic meters. There are a number of assudes of more than 100 million cubic meters, and in general, those constructed by the Inspetoria itself have a capacity of several million cubic meters. In addition, large land-owners, with state or federal aid, have built several of about one million cubic meters, and many smaller ones.

The fishes which naturally entered and multiplied in these impounded waters have always been sought for eagerly by the people. But the fish fauna of the region is poor, which is natural from the fact that only the more resistant species can maintain themselves in the adverse conditions which prevail in the hydrographic basins. The rivers permit free migration during the rains, but soon afterward they become dry and are planted to crops. The fishes which remain in pools die before the end of the dry season, and only those are saved which were able to reach the large assudes. In contrast to the almost

fantastic qualitative and quantitative abundance of fishes of the Amazon basin and the considerable richness of the Sao Francisco River, the region of Northeast Brazil, which lies between these two rivers, is very poor in its fish fauna. These waters of uncertain duration have only those species whose extraordinary resistance and adaptability is demonstrated by the fact that they are distributed from Central America to Patagonia. Such are the *trahira* (*Macrodon malabaricus*), a predacious form; the *curimata* (*Prochilodus*), a mud-eater; some species of *Tetragonopterinae,* equivalent to the minnows; and several other relatively small forms. In some hydrographic basins the *piranhas* (*Serrasalmonidae*) are abundant, and in others they are absent.

The people of Northeast Brazil are satisfied with these fishes for the reason that they know nothing better. Only the first two mentioned attain a weight of 1½ or 2 kilograms, and both have many troublesome bones. The quantity in some measure compensates for the poor quality. Annual catches of 20 to 40 thousand of these fishes in assudes of one million cubic meters, or less, are not rare. However, such catches can be made only with the flew-net when the water has lowered to a depth of a few meters. The *trahira,* being carnivorous, can be taken on the hook, but not the *curimata.* In places where there is no large market nearby, because of the lack of ice, most of the catch must be salted, with consequent loss of value.

Now, after the construction of many large assudes, which offer better conditions for the fishes, there is an opportunity for a rational programme for the improvement of the inland fisheries. That is the aim of the Commissao. After a brief survey of the situation, the following general plan was adopted: (1) In order to show some results of practical value, to introduce some species of good eating qualities which can be taken by hook; (2) at the same time proceed with studies of limnology and of various fisheries problems, in order that, on the basis of the knowledge so gained, to intensify and improve the practical work.

In the execution of the first part of this programme, the following policy was adopted: (1) not to introduce foreign species, thus avoiding the risk of causing, involuntarily, irreparable damage; (2) to choose fishes of different feeding habits, so that they might live in the same waters without competing for food; (3) to transport individuals sufficiently large that a high percentage might escape enemies which beset the younger stages. With these things in mind, the following species from the Sao Francisco River were considered useful: the *mandy* (*Pimelodus clarias*), the *pira* (*Conorhyncus conirostris*), the *sofia* (*Pachyurus francisci*), and a fourth species related to the *curimata* (*Prochilodus*) of the assudes. The *mandy* attains a length of 50 cm. and a weight of 2 kilograms, and feeds almost exclusively on chironomid larvae. The *pira* eats worms, ostracods, and small molluscs, and reaches a length of 80 cm. and a weight of 7 to 8 kilos. Both can be taken by hook, and the meat, having few small bones, is of at least

average quality. *Sofia* is a sciaenid adapted to fresh water and it has excellent flavor, similar to that of good salt-water species. It attains a length of 60 cm. and feeds principally on large adult and larval insects. The fourth species, which has a diet like that of the related *curimata,* has a body nearly oval in cross section, so that with the same length as the *curimata* it reaches 7 or 8 kilos of weight. Introduced into assudes, it may dominate or eliminate the smaller form, but if so, the fishermen will be the gainers.

In spite of difficulties imposed by poor roads, the distribution of fishes from the Sao Francisco River has reached eight independent hydrographic basins, with the planting of 26,000 *mandys* ranging from 10 to 15 cm. in length. These fish develop very well in the assudes, where they find chironomid larvae in extraordinary abundance. In seven months, individuals with a weight of 60 grams grew to 600 gm., and in 17 months reached one kgm. Work has been concentrated on this species because it can be obtained in large numbers and because it can be transported with slight loss.

Tropical waters have been studied very little, and before the beginning of this investigation virtually nothing was known of the physical, chemical, and biological conditions existing in the assudes. In planning a programme, the first question was whether to make it extensive or intensive, that is, whether to study many waters superficially, or a few in greater detail and at frequent intervals. Decision was made for the latter. Headquarters were established in Campina Grande, Parahyba (elevation 500 meters), and four assudes were selected for study. They were studied over a period of a little more than a year, from the beginning of the rainy season of 1934 to the middle of the rainy season of 1935.

The assudes are shallow and small in extent. Due to the alternation of wet and dry seasons, they undergo marked seasonal changes in volume. Transparency is low and the waters have a yellow-brown color. There is no definite period of thermal stratification, but temporary stratification, because of high temperature and rapid decomposition of organic matter, sometimes leads to exhaustion of dissolved oxygen in the lower water. The waters contain much chloride and carbonate. Two of them have little phytoplankton and the surface water is usually slightly acid or slightly alkaline to phenolphthalein. The other two have an abundance of blue-green algae, and are usually very alkaline. Plankton crustacea are fairly abundant in all four.

Rooted vegetation is scanty, and the invertebrates of the littoral show little variety. Bottom organisms in the deeper water are also few in species, but the chironomid larvae are abundant.

In addition to the study of these four assudes, excursions were made over a considerable part of the semi-arid region. Material obtained on these excursions has made possible maps of the distribution of plankton organisms and of the salinity of the waters. As the invertebrate fauna is quite unknown, collections have been made and sent to

specialists for identification. At the time of writing (August, 1935), headquarters are being changed to the State of Ceara and it is planned to make a detailed study of some of the larger and deeper assudes there.

One of the most important studies for the progress of fish culture in South America is that relative to the spawning activities. As the senior author had already determined at Sao Paulo, in southern Brazil, the fishes have the gonads well developed some months before spawning; the sperm show prolonged motility in water, yet the female does not extrude the eggs except under favorable meteorological conditions. Attempts at artificial fertilization before the rains are uniformly unsuccessful. On the day following a good rain the eggs flow freely; the ovary is entirely empty, and with artificial fecundation one obtains nearly 100 per cent of the eggs in segmentation.

It is evident that, because of this dependence on favorable natural conditions and the rapidity with which spawning is concluded, one can not be certain of obtaining a sufficient number of eggs for artificial raising on a large scale. For this reason, in 1932, the senior author tried forcing the extrusion of eggs by injection of hormones. A solution of the problem was found in the injection of extracts of hypohysis, in which the studies were aided by Dr. Dorival A. Cardoso. By this means ripe eggs can be obtained at any desired time. Injecting extract of ½ hypophysis in a *piaba* (*Tetragonopterus*), or of 2 to 4 hypophyses in a *curimata,* there was a flow of ripe eggs from 6 to 10 hours afterward. The *piaba* expels only a part of her eggs, while the *curimata* expels all at one time, as already observed in nature. Dry hypophyses, as prepared by Dr. Cardoso, have the same effect as fresh ones, so steps are being taken for its commercial production.

Development of the eggs of the two species mentioned takes place with very little care, yielding nearly 100 per cent of hatched larvae, without even changing water in the dishes. The time of development varies from 12 hours at 28° Centigrade, and 18 hours at 23°, to 36 hours at 18° for the *piaba;* and 29 hours at 24° for the *curimata.* The larvae of both forms swim quite freely from the time of hatching. Three days later the anus is opened and they begin to take food, which consists of algae, protozoans, and small crustaceans. The eggs are rarely attacked by *Saprolegnia.* Little is known of the feeding habits of the young post-larval stage. These more easily fall victims to the fungus. As was shown in a report on the *curimata* (Ihering and Azevedo, 1934), the growth of this species is very rapid. In four months it reaches 17.6 cm., and at one year of age the males attain 25 cm. and 430 gm., and the females 28 cm. and 800 gm.

We must refer briefly to the two predacious species which are noxious to fish culture: the *trahira* and the *piranha.* The *trahira* is found in all the inland waters of Brazil, but its ecology has not been sufficiently studied. It has been considered as a great enemy to fish culture. Incomparably more destructive is the *piranha* (*Serrasalmoni-*

dae of various genera and species), a true pest, not only for fishes and other aquatic vertebrates, but for cattle and man also. The exploits of this fish are well known. In a few moments a school of them can tear the flesh from an incautious swimmer. Fortunately there are several river systems of Northeast Brazil in which it does not exist, and in the Sao Francisco River, although present, for some reason it does not cause trouble. But in the Jaguaribe River of Ceara, and in the Piranhas River of Rio Grande do Norte and western Parahyba, it is greatly feared. The programme of the Commissao in the future must include a study of means to combat this undesirable fish.

At the time of writing, the staff of the Commissao includes four full-time investigators, two students, and two visiting investigators. Of the 12 reports published, six are popular in nature or of local interest. For the guidance of those who may be interested in the scientific results, a list of the remaining papers is given below.

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THE PRESERVATION OF WHITEFISH PRODUCTION IN LAKE WINNIPEG

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The whitefish fishery on Lake Winnipeg is the largest of its kind for one lake in America, so the preservation of its productivity is a matter of vital concern for all interested in the fishing industry.

As we have seen virgin lakes teeming with whitefish reduced after thirty years of commercial fishing to the point where whitefish production was almost negligible, a retrospect may help in forming plans for the preservation of the Lake Winnipeg industry.

Thirty-eight years ago Lake Winnipegosis was literally full of whitefish, but its production of this species today is very small. When the lake was first fished in 1897 fishermen could only use a small number of nets, as six webs of net would catch as many fishes as the twenty-four-foot sail boats could carry. Why then should it be that the whitefish population has been so reduced in a lake that still has an abundance of whitefish food in its waters?

It is unfortunately true that fishermen are not always honest with themselves nor true to their own best interests, and for momentary and immediate profit sacrifice their future. It is from such carelessness in the early years of commercial fishing that many of our lakes are now suffering.

Fishing whitefish in spawning season (closed season) and salting the catch.

Fishing 4¼″ mesh nets on whitefish grounds and taking immature whitefish.

Fishing a larger outfit of nets than the boat would warrant, causing nets to be left in the water unlifted, with consequent rotting of fish.

Deliberately throwing suckers and other offal into the lake when summer fishing, and leaving suckers and offal on the ice in winter time.

The Manitoba winter fishing season has for some years opened on November 10th. This was so early—sometimes before the lake was frozen over, and nearly at all times before travel on the ice was safe, making it impossible for enforcement officers to patrol the northern areas of the large lakes, so that fishermen more or less could start to fish any time they wished. The natural spawning grounds of whitefish were favorite locations for fishermen's winter camps, and for years when the market warranted it, large quantities of whitefish were taken from the spawning grounds, salted and sold when the buying season opened. This killing of female whitefish before they had spawned, when they were gathered in large numbers on the spawning grounds, has no doubt been the main cause in reducing the whitefish population on Lake Winnipegosis.

Fishing on whitefish grounds with 4¼-inch mesh nets during the licensed wall-eyed pike or pickerel season in summer has been the

cause of too many immature whitefish being taken, fish that had not reached the reproducing age. This no doubt is a vital factor in depletion of whitefish, particularly in relatively shallow lakes where it is difficult to distinguish or set aside definite areas for each variety.

Fishing more nets than the boat would warrant is a fault of the over-zealous fisherman. Throwing offal overboard and leaving offal on the ice in winter time are faults of careless fishermen, or deliberate violators of Fishery Regulations.

All these violations or abuses are hard to eradicate by enforcement, and a studied programme of education would seem the better way to treat the matter. It will be readily seen by all that taking whitefish at spawning time destroys ova; taking immature fish is also a loss of reproduction, but fishing more nets than can be properly handled, and throwing offal into the lake have a detrimental effect on whitefish grounds. In the first place, whitefish will always leave areas where the lake bottom is polluted with decaying fish. Secondly decaying fish provide food for crayfish and these crustacea multiply. Crayfish are excellent feed for wall-eyed pike and where plentiful the wall-eyes increase. Therefore, it is reasonably safe to assume, and actual happenings on Lake Winnipegosis appear to prove, that where wall-eyed pike increase and invade the whitefish grounds, the whitefish are on the decrease.

To return to Lake Winnipeg. It has come to the notice of the writer that large wall-eyes are being caught in whitefish nets on whitefish grounds at the north end of the lake. This was unknown in earlier years. This would seem to be an indication that the whitefish population is on the decrease, even though enlarged fishing equipment may catch the weight limits allowed each season. If there is a decrease in the whitefish population it is due to the fishing industry, and in correcting the causes of depletion, fishermen, fish buyers and all interested in the industry should co-operate, and sacrifice, if necessary, to ensure sufficient whitefish reproduction to maintain the fishery.

The Administration early recognized the importance of adequate safeguards and protection, particularly to the whitefish fishery. In 1890 only six or seven years after the first meagre commencement of commercial summer fishing on Lake Winnipeg, representations having been made to the Government of depletion of whitefish, Mr. Samual Wilmont was appointed Commissioner to investigate fully conditions of the lake. Based on his report, restrictive regulations were promulgated in 1892 defining closed seasons based on the spawning time for each species of fish as well as closed areas of recognized spawning grounds. The earliest closure was that of the spawning grounds of the Dauphin (Little Saskatchewan) River. For nearly forty years there has been an entire closure from the middle or end of August till freeze up. On all the northern areas of Lake Winnipeg this constitutes close to three quarters of the water area of the lake and is recognized as the whitefish grounds.

To bring to fishermen and fish producers a realization of their responsibilities in maintaining fisheries production, an energetic educational campaign is essential. This should even extend to schools located at or near fishing centres, as from these schools future fishermen are receiving training. Only by education can we eradicate such practices as throwing offal overboard, the continual using of small mesh nets and the greed that leads to having more nets in the water than can be properly handled.

Discussion

Mr. Thaddeus Surber: Does anyone know to what extent, if any, they have made an attempt to introduce whitefish fry into these waters?

The President: Can anybody answer Mr. Surber's question?

The Secretary: Mr. Rodd could tell us if he were here.

Mr. Thaddeus Surber: In all Minnesota lakes and all the lakes north of the line there is such a superabundance of burbot that practically no whitefish or lake trout eggs survive the winter months. Therefore deposits of eggs of those two species under natural conditions must practically disappear, and inasmuch as no burbot are taken by the angler we find in the destruction of these burbot ample recompense for a few game fish taken by the commercial fishermen.

REMARKABLE PRODUCTIVITY OF LAKE DAUPHIN

A. G. Cunningham

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One of the most interesting of commercially fished lakes in Manitoba is Lake Dauphin, situated in Townships twenty-five to twenty-eight, ten miles east of Dauphin. The lake has an area of nearly 200 square miles, twenty miles in length and varying from seven to twelve miles in width. It is very shallow, the greater part averaging three to five feet. The greatest depths average ten feet and are found in a channel extending lengthwise through the middle of the lake. This shallow basin has produced an amazing amount of fish-food. In 1929 Lake Dauphin led the important winter fishing lakes in pounds of fish produced per square mile. The table includes the two nearest competitors.

Lake	*Area (sq. miles)*	*Lbs. per sq. mile*
Manitoba	1,817	3,428
Winnipegosis	2,086	2,084
Dauphin	200	7,350

1929 was an exceptionally productive year for Lake Dauphin, but it always rates high in comparison with commercial fishing waters of the Province. Fifty per cent or more of the catch is wall-eyed pike or pickerel.

Winter fishing in such shallow water necessitates the use of very narrow gill nets. The legal mesh is four inches extension measure. Usually the net used is only six meshes deep and later in the season, when the ice is heavier, only four meshes. These nets are set very close together, only a few yards between nets on the favorite setting places near river mouths. In good years the nets are lifted every day.

The seasons of 1929, 1930, 1931, and 1932 were dry, and in the fall of 1932 the water level was three feet below the normal mean level. Fish production naturally declined with the water level but is still nearly double the catch of ten years ago. Larger fishing outfits are not the only reason for the increased production. Local opinion gives two reasons for the heavy production in such shallow water: First, the fish taken from Lake Dauphin belong to, and migrate from, Lake Winnipegosis. Second, the fish are indigenous to Lake Dauphin, spawning in the lake and the six tributary streams from Riding and Duck Mountains. These streams and some of the larger creeks have a large flow of soft water in the spring of the year, and are then ideal spawning grounds.

A shallow prairie lake, entirely dependent on drainage, Lake Dauphin was affected by the dry years. Grave fears were entertained for its fishes, which have been of inestimable value to a large settlement of fisherman-farmers. In 1933 the Manitoba Government built a dam across Mossy River, the outlet of the lake, which empties into Lake

Winnipegosis. There is an efficient fishway in this dam, and in addition the stop logs are opened during the main spring run of fish. With sufficient water below the dam there is a heavy run of wall-eyed pike through the dam during the spring and fall freshets.

The abundant precipitation of 1934 raised the water level one foot, and the heavy rains of this season added another three feet. The dam has been opened and water levels are high enough for the free passage of fish. These changes in water levels may influence the future production of Lake Dauphin and will be kept under observation.

EXPERIMENTAL STOCKING OF SPECKLED TROUT FROM THE AIR

GUSTAVE PREVOST

Department of Public Works, Game and Fisheries, Quebec, Canada

At the suggestion of Mr. B. W. Taylor, Director of Fish Culture for the Province of Quebec, I took the advantage of an airplane trip, in the month of October, 1934, to see from what height trout could be dropped into water without harm.

A three-pound trout, placed in a sack with a float attached was dropped from a height of 1,000 feet. No external injury could be seen. A pound trout was dropped in the same manner from 200 feet. These two trout are still in the hatchery alive and well. However the eggs taken from these two, shortly after their adventure, died within a few days of fertilization.

Three fingerlings averaging four grams each were placed in separate metal containers filled with water. Due to mischance the containers landed, not in the lake but in a potato field, and from a height of one thousand feet. Only one was found. This fingerling was soon swimming normally in a separate trough.

This was sufficient to convince me that the stocking of lakes from considerable heights was practicable, but it is hardly sufficient to convince everyone. In July, 1935, trout were dropped free from an aeroplane at a height of two hundred feet, into specially prepared nets, fifty feet by seventy-five feet. Three trout of 120 grammes were recaptured in good condition. They were taken to the nearest hatchery to see what effect, if any, the fall might have on the genital organs. A week later another effort was made and from the trout recaptured, none survived. It was thought that they may have made contact with the plane as they were dropped. This was quite possible due to our makeshift arrangements.

At the end of August, with larger nets and a more suitable plane, thirty fish were dropped from a height of one hundred feet and recaptured. Fifteen were dead and fifteen living. These fish were dropped from water with a temperature of 10° Centigrade into lake water of 29° Centigrade. To check this factor thirty fish of the same size (about 120 grammes) were placed in the nets by hand, that is from water of 10° Centigrade to 29° Centigrade. After ten minutes, nine were dead, after twenty minutes, twelve were dead, and after 45 minutes, only nine of the thirty were alive. The conclusion follows that trout of this size can be dropped from this height without harm, even under unfavorable conditions.

A few days later fingerlings weighing from one to three grammes were dropped from a height of 100 feet. A total of 631 of these fish were recaptured from our cheesecloth nets. They were removed and taken to the hatchery. The total loss was forty eight. Sixteen of these

were injured by falling on the wooden framework necessary to keep the compartments of the net together. External injury was evident on these fish. The remaining loss of thirty-two is to be explained by the fall, or by the trip to and from the hatchery.

Fifty-seven two-and-one-half-year speckled trout were dropped from a height between 125 and 300 feet. Six of these were dead when recovered, two with broken gills and four with wounds on the body.

The temperature of the water from which the fish were dropped was 9° Centigrade and the lake water 21° Centigrade.

It seems to me that these experiments are sufficiently conclusive to demonstrate that the stocking of lakes from the air is not only possible but practical.

A TRANSGRESSION OF MARGINAL WATERS OVER THE SCOTIAN SHELF

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In late September of 1934 a brown jellyfish was present in large numbers in the coastal waters in and about Halifax harbour. To some, the presence of these jellyfish made bathing uncomfortable, while to fishermen, the unfamiliar type was a matter of note. Attention was thus drawn to the form on September 17th, while one of the authors was engaged in observational work in Halifax harbor. Regular weekly tows in Halifax harbour showed the presence of this jellyfish on September 20th and 27th, 1934. In the course of further work by the Biological Board motor vessel *Zoarces,* Captain A. E. Calder, to the west of Halifax, quantities of these jellyfish were obtained at many stations between Halifax and St. Mary Bay, Nova Scotia. It occurred as far offshore as LaHave bank and at depths down to twenty metres. The dates of occurrence at these places were from October 3rd to 11th, 1934. The distribution of the form as revealed by this cruise of the *Zoarces* is shown in Figure 1.

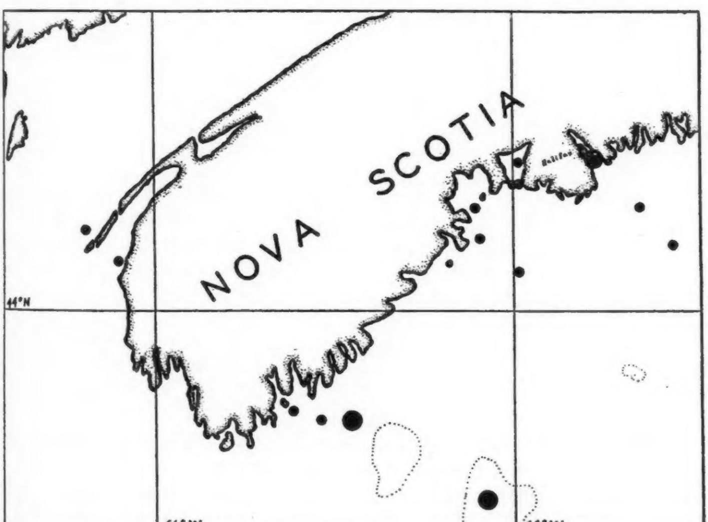

Fig. 1.—Distribution of *Pelagia* in the area investigated in September-October, 1934. Small solid circles indicate the presence of the form; large solid circles indicate an abundance of it.

This species of jellyfish was hitherto unknown from Canadian waters although well known in the warm waters associated with the Gulf Stream. Dr. H. B. Bigelow, of the Woods Hole Oceanographic Institution, identified a specimen as *Pelagia noctiluca* and classified it as an oceanic warm water form. Consequently we have very definite indications of a transgression of, at least, marginal waters (i.e. those bordering the continental shelf) over the Scotian shelf. Further evidence is offered from observations of salinities and temperatures made in Halifax harbour.

Surface Water Temperatures and Salinities in Halifax Harbour

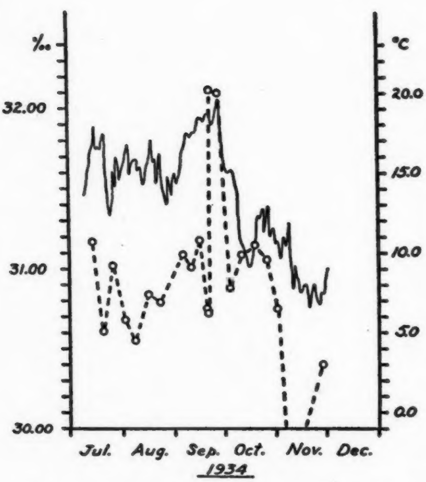

Fig. 2.—Surface temperatures and salinities in Halifax harbor.

Daily surface temperatures, and periodical observations of surface salinities in Halifax harbor are plotted in Figure 2 for the period July to November inclusive. The daily mean surface temperature (readings twice daily) was as low as 13.0° C. on August 28th and from this point increased fairly regularly until a temperature of 19.6° C. was attained on September 28th. The resulting mean surface water temperature for the month of September was 17.5° C. which is 2.4° higher than the average mean for the past nine years (shown in Table 1). It is thus evident from the observations that abnormally warm water was present in Halifax harbor during the latter part of September.

TABLE 1.

September mean surface temperatures for the years 1926-1934, inclusive. Average of the means 15.1° C.

Year	1926	1927	1928	1929	1930	1931	1932	1933	1934
Mean	14.4	12.9	16.0	14.6	16.1	15.4	15.5	13.5	17.5

The surface salinities which varied considerably in July, August, and early September, increased sharply from a value of 30.72 per mille on September 21st to 32.12 on September 22nd and these comparatively

high surface salinities prevailed until sometime between September 27th (salinity 32.10 per mille) and October 4th (salinity 30.88 per mille). It is thus evident that surface water of a comparatively high salinity was present in Halifax harbour in late September.

Surface Water Temperatures and Salinities over the Scotian Shelf

That such surface waters of comparatively high temperature and salinity, as experienced in Halifax harbour in late September, were typical

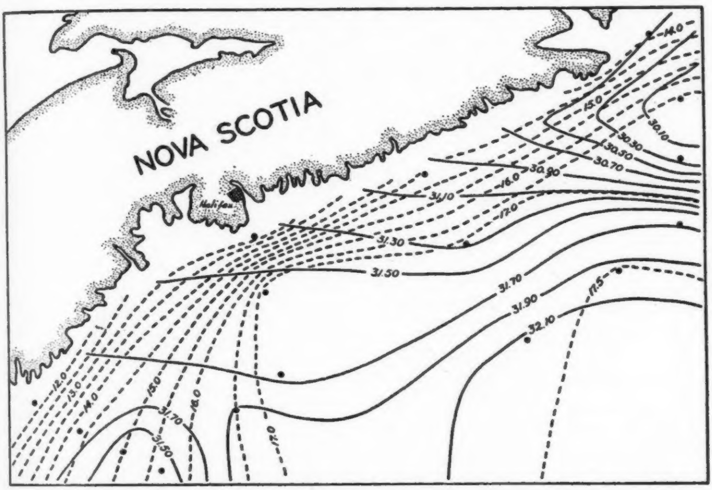

Fig. 3.—Distribution of temperatures and salinities on the Scotian shelf in August 1934.

of the marginal waters at the edge of the continental shelf is attested to by the distribution of surface temperatures and salinities on the Scotian shelf for August, 1934 (Figure 3). Surface temperatures greater than 17.5° C. and surface salinities greater than 32.00 per mille are to be located about seventy miles offshore. From observations in this area during the years 1932 to 1934 inclusive, it is known that the surface salinities were approximately 0.5 per mille higher in August, 1934, than in the same month in either of the two previous years. This indicates that the transgression was in progress even during the month of August.

Bottom Water Temperatures and Salinities in Halifax Harbour

The bottom water temperatures and salinities in Halifax harbour throughout the period July to November inclusive are illustrated in Figure 4. Temperatures and salinities varied but little during the months

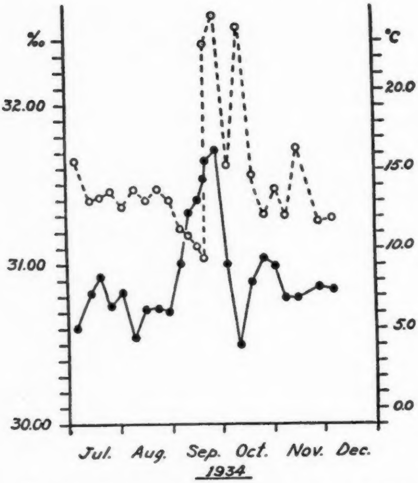

Fig. 4.—Bottom temperatures and salinities in Halifax harbor. Solid line—temperatures; broken line—salinity.

of July and August. The chief disturbance is noted in the early part of September when the bottom temperature increases from 6.0° C. on August 30th to 14.4° C. on September 20th. Coincident with the rise in temperature is a lowering of the salinity from 31.40 per mille on August 30th to 31.04 on September 20th. This increase of temperature of the bottom waters coincident with a decrease of salinity is indicative of a replacement of bottom waters by surface waters (Hachey, 1934) and is the result of the reaction of the waters to steep atmospheric pressure gradients. A further increase of bottom temperature takes place after September 20th, until, on September 27th the bottom water temperature is 16.2° C. The bottom salinity, however, increases from 31.04 per mille on September 20th to 32.38 on September 21st and to 32.57 on September 27th. The increasing temperatures on the bottom are indicative that replacement by waters of surface origin is still taking place, but the sharp increase in salinity indicates that the water of surface origin has been drawn from considerable distance offshore, and offers further verification of the transgression of the Scotian shelf by marginal waters from the edge of the continental shelf.

Discussion

While at the present time but little is known of the factors concerned with the transgressions of marginal waters over the Scotian shelf, attention has been drawn to the question and it would seem that an analysis of conditions in Halifax harbour from year to year will throw further light on the problem. Available temperature data in Halifax harbour are fairly complete for the period 1926 to 1934, but the corresponding salinity data were destroyed by fire some three years ago. The subject of transgressions has been of considerable concern in the region of the Grand banks (Le Danois, 1932), and the periodicity of these transgressions has presumably been established. It is perhaps reasonable to sup-

pose that such periodicity might be expected in connection with transgressions of the Scotian shelf.

Summary

1. In late September of 1934, a brown jellyfish (*Pelagia noctiluca*), hitherto unknown from Canadian Atlantic waters, was present in large numbers in the coastal waters in and about Halifax harbour. Later in the season, quantities of these jellyfish were taken in tows from Halifax to St. Mary Bay, N. S. As this species of jellyfish is well known in the warm waters associated with the Gulf Stream, its presence on the coast would suggest a transgression of, at least, marginal waters (i.e. those bordering the continental shelf) over the Scotian shelf.

2. An analysis of variations in temperature and salinity data, throughout the period July to November inclusive, indicates quite clearly that the area of the Scotian shelf was transgressed by waters of comparatively high temperature and high salinity which were of at least marginal origin.

Acknowledgments

The authors wish to thank Dr. H. B. Bigelow for the identification of the jellyfish and Mr. R. A. McKenzie for information on its presence in tows in Halifax harbour.

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THE NEED FOR PLANNED WATER UTILIZATION WITH AQUICULTURAL SUGGESTIONS

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The program of land planning which has recently been inaugurated on a large scale by the Federal government calls attention to the possibilities and need for planned utilization of the inland water resources. There are federal and state departments, corporations, clubs, and individuals interested in their several conflicting ways in these resources, and it should be possible to formulate and administer a plan of utilization which would make the most effective application of the potentialities of every body of water.

The land planners are interested in the water only insofar as it affects the land, and the water resources have potentialities which entitle them to far greater consideration. Every water area should be inventoried and classified according to its present utilization and according to its fitness to perform the functions of transportation, generation of power, direct consumption by man and domestic animals, removal of domestic and industrial wastes, production of plant crops for use as animal food or as fertilizers, production of animal crops for use as food or game for man, and the beautification of landscapes.

Water areas should be rated according to their respective capacities for performing the various possible functions, using an outstanding case of utilization as par for that function. This would make possible the comparison of water areas in widely separated regions as to functional capacities, and would provide a basis for comparing the past, present, and future utilization of particular areas. The planned effective utilization of particular water areas should be based upon present and future needs, and should recognize the economic and social claims of mutually antagonistic interests.

It must be recognized that most ponds, lakes and streams are only places where the underground waters are exposed to view. Underlying the fields it makes possible the production of plant crops, some of which are consumed directly by man and some indirectly by conversion into the flesh of animals. Similarly, waters which are exposed as ponds or streams cover land, and certain kinds of plants grow with roots in the land under water and with stems and leaves in water rather than in air. These aquatic plants derive their sustenance from the soil and when the green matter in their leaves is activated by sunshine the same chemical reactions occur that occur in plants in air. There are also many forms of very small plants which do not have rooted attachment to the soil but live suspended in the water, and these are likewise dependent on sunshine, and derive their nourishment from materials from the soil dissolved in the water. The plants, small and large, are eaten by certain

very small forms of animals which are in turn eaten by fishes. A few species of fish consume plants directly, but most species have digestive glands which restrict their diet to animal matter, and are therefore dependent upon the transformation of plants into meat by the intermediate small forms, principally entomostracans. Most species of game fish are meat eaters which consume entomostracans while they are small, and prey upon smaller fish when they are large.

Although the production of a crop of fish is only one of several services performed for human benefit by water areas, the demand is commonly made that all waters produce fish regardless of possibly greater value when used for other purposes. Those water areas which could be of most service to the most people by producing fish should be managed in such manner as to yield the maximum crop. The fish production of water areas is correlated directly with the richness of the bottom soil, and some areas are naturally more productive than others. Just as there are land areas which are too poor to permit profitable farming, there are poor water areas where efforts at fish production can never yield satisfactory returns.

Whether producing beef or bass, therefore, man is utilizing the capacity of plants to utilize solar energy, the organic and inorganic matter of the soil, and the water beneath the soil. The principles that underly the operation of an air-covered land area for the production of beef are essentially the same principles involved in the production of bass. The principal obstacles to fish production are connected with the following facts: (1) the fish occurring in every water area are of many species and diverse individual habits; (2) the plant forms and intermediate animal forms are diverse in character and utility; (3) changes of the physical nature of the fish community are tremendously variable and not subject to control; (4) the water areas and animal habits make control of individuals constituting a fish community impossible; (5) the range of individual fish cannot be closely restricted; and (6) the harvest is haphazard and non-controllable.

The Supreme Courts have decided that the supply of fish in public waters constitutes an unallocated natural resource which remains the property of the people of their respective states, and the management of this resource has been assigned to a department of state government. This resource is not like a mineral resource, to be mined until the supply is exhausted, but like an interest-bearing capital sum, invested in live stock, which by careful manipulation can be made to yield an annual income. The profits from the investment consist of an annual crop of fish. Angling is the prevalent popular method of harvesting this wild crop, and the number of people who share in the harvest is only a small fraction of the number entitled to share in it. If the fish harvested from all public waters were to be marketed at their actual value there would be dividends to be shared among all residents, which would be very satisfactory to the people who do not go fishing. Only a small per cent of the people who do go fishing are required to buy licenses, and yet the

governmental regulation of fish cropping in most states is financed only by the sale of fishing licenses, and in most cases the funds are not adequate to permit proper performance of the task.

Since the angler is interested in removing only large fish, his complaint that fishing is poor can only be satisfied by increasing the water's yield of large fish. The reduction in numbers of adult individuals of a species in a particular body of water appears to be due partly to overfishing and partly to the failure of large numbers of small fish to reach adult size. When minnows and crayfish are abundant they bear the brunt of the predaceousness of large game fish. When minnows and crayfish are scarce the small game fish become the prey in larger measure than usual, and the present scarcity of minnows and crayfish, due to their general use as bait, is probably the principal cause of the failure of many small game fish to reach large size.

For several decades efforts at fish cropping the waters of a state have consisted principally of attempts to supplement native reproduction by the addition of more fish from other sources, and to limit the harvest by closed seasons and daily bag limits. Lately this has been extended by local attempts to improve the habitability of natural waters by creating new holes in some streams and impounding the water behind small dams in others, and by inserting gravel shoals for spawning and brush entanglements for the protection of young in some lakes. However, it is the writer's opinion that the task of fish cropping the waters of a state involves considerably more than these procedures, and the following outline is suggested with full realization of its incompleteness but with the hope that it may serve as an approach to a better understanding of the nature of the task.

(A) Managed production in natural waters:

- *a.* Managed production of organisms constituting the food.
  1. Protection of minnows, crayfish, etc., against removal for use as bait.
  2. Supplemental production of forage fish and crayfish in state fish ponds.
- *b.* Development of series of alternating riffles and holes in streams, and spawning shoals and shelter in lakes.
- *c.* The construction of reservoirs along stream courses to provide depths for wintering fish and barriers to prevent downstream migration.
- *d.* Reclamation of polluted areas by correction of conditions detrimental to fish welfare.

(B) Game fish produced on State fish farms should be used in supplement production in natural waters. The introduction of quantities of fingerling bass tends to compensate for the excessive withdrawal of adult fish by adding young fish that would have been produced if the brood stock had been adequate. Since the heaviest losses occur among eggs and very small fish, the addition of a number of six inch fish in the fall is equal to the production of many times that number of fry the previous

spring. The introduction of adult fish immediately before the spawning season is an effective way of providing brood stock to waters that have been too heavily fished the previous year. The tendency of many species to migrate downstream in the fall and upstream in the spring makes it advisable to stock streams with these species in the spring.

(C) The State fish farms should also be used for the development of superior strains of the various species of game fish by selective breeding. It is probable that strains superior to the wild native stock in hardiness, growth rate, ultimate size, and reproduction could be developed and used to improve the quality of the fish in natural waters.

(D) The harvesting of the fish crop should be managed by the State. It is essential that:

a. The brood stock be protected during the spawning season.
b. The harvest be limited to certain year groups for each species to permit the attainment of sexual maturity and one spawning before catching.
c. The fishing be regulated so as to distribute the crop among the maximum number of fishermen.

HOW TO ESTIMATE THE DAILY FOOD CONSUMPTION OF FISH UNDER NATURAL CONDITIONS

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With the help of modern methods of investigation we can fairly accurately estimate the total amount of plankton in a lake, the total amount of bottom fauna, the total amount of organic matter in the water, the rates of growth of fishes, etc., and even in certain cases the total amount of fish in our waters. But our knowledge regarding the daily consumption of fish under natural conditions is still very incomplete. However, we cannot fully understand the exchange of organic matter under the surface of water, without the definite knowledge of how much fish eat, and of what part of the food is used for the building of the fish body. Rearing and feeding experiments in aquaria or small tanks cannot solve the whole problem, as the conditions under those circumstances are very different from the natural ones, where the fish can move freely in a large area and select such kinds of food as they desire. Moreover, there are seasonal changes in temperature in natural waters which influence not only consumption and the rates of digestion, but also the amount of available food; and under natural conditions in the majority of our species, the food consumption changes with the age of the fish. The alkalinity of water also influences greatly the rates of growth and probably also the rates of digestion. As a general rule, fish grow much faster in alkaline than in acid or neutral waters. The whitefish in Lake Winnipegosis, for instance, increase in weight about four times as fast as in Trout Lake, Wisconsin (Hile). Speckled trout in Maligne Lake, in Jasper National Park, grow five or six times faster than in some acid or neutral waters of Prince Edward Island. These examples show that the daily consumption of the same species is not constant, but a function of many factors, such as temperature, alkalinity, etc., and, therefore, it must be determined in each particular case separately. Some years ago I estimated the daily consumption of whitefish (*Coregonus clupeaformis*) in Manitoban Lakes by the following method. The fish in question is practically a night feeder and during the summer the rate of digestion is rapid. Gill nets were set at sunset and lifted at sunrise. It may be assumed that the average stomach content will show a half-feed condition, because those fish which are caught just after sunset will have empty stomachs and those caught just at sunrise will have full stomachs. Exactness will depend on number of fish examined. This is the simple example of estimating food consumption when fish feed mostly at night. The same method can be applied also if fish feed throughout the day and night. In the latter case the daily consumption must be theoretically twice as much as that for day or night feeders.

The method described above is not always convenient in practice and can not be used with fry or such small fishes as smelt, stickleback and

others, which serve as food for larger fishes. For this case another method is suggested. It is easy to catch a number of small fish by a minnow seine or other means. A sufficient number of them, say one hundred, should be preserved at once, as soon as they are landed, and the total amount of the stomach contents only (not food in the intestine) should be carefully washed into small Petri dishes, counted and weighted. Then by dividing the total amount of food by the number of individuals we obtain the average stomach content of any species at a given time under certain temperature and other conditions. Another lot of live fish should be placed at the same time in a bucket or in some other convenient vessel, filled with water freed of its plankton content, and placed in the same stream or lake in a protected place, in order that the temperature of the water in this vessel will not change during the period of experimentation. It is not difficult, then, to examine about ten fish each hour or two and to find out the rates of digestion. Temperature, of course, should be checked. If all the food passes from the stomach to intestine during a period of twenty-four hours and if it has been determined that the fish in question is feeding both day and night, the average stomach content will represent the daily consumption of fish. In the case of more rapid or slower digestion, the daily consumption could be calculated by means of the following formula:

$$D = A \frac{24}{n}, \text{ where:}$$

D = the daily consumption during the time of experiment,
A = the average amount of food in the stomach at the time of experiment,
n = number of hours necessary for passing all the food from stomach into intestine (rate of digestion).

The exactness of such determination will depend on the number of specimens examined and this calculation will have value only for the period of experimentation. As such an experiment can be easily repeated each month, very valuable information regarding daily, seasonal and annual consumption of many species of fish can be obtained.

Such an estimate is, perhaps, open to criticism and is offered as a suggestion.

A RECORD OF *OCTOMITUS SALMONIS* MOORE FROM QUEBEC

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In June, 1935, I commenced a survey of the speckled trout fishing in Lake Edward, Champlain County, Province of Quebec. This study has been instituted to determine the causes of the present poor fishing. It has steadily decreased in the past twenty years and now compares poorly with that afforded by adjacent waters.

As the result of an examination of over thirty trout from this lake, it is apparent that the problem is chiefly parasitological. Practically one hundred per cent of the adult trout are parasitised by three forms, a nematode, and acanthocephalan and a trematode. The fish appear to be quite tolerant to the latter two. Serious damage results principally from the formation of multiple visceral adhesions as a consequence of large numbers of nematodes in the mesenteries and coelom. The study of these three forms is continuing and will be fully reported in a later paper.

The purpose of the present paper is to record the presence of *Octomitus salmonis* in two of the trout which were examined in the course of the study of the fish in this lake last spring.

Although very complete data has been published dealing with the role of *O. salmonis* in hatcheries, the occurrence of this parasite in trout under natural conditions has previously been reported only in cases where infection could be traced to contamination during rearing under hatchery conditions or to the fact that the fish were living in water coming from a hatchery where the parasite was present (Moore '23). The present record is distinct from the above and is significant in indicating the possibility of introducing this parasite into a lake by the planting of infected fish. For the reason given below, it seems improbable that this is a case of natural infection and it is to be regretted that there seems no possibility of obtaining data to show the role of such infected adults as a source of octomitiasis amongst the fish in the lake.

Only two of the thirty specimens examined were infected and neither showed any external indications of being parasitised, both being of good form and color. In the one, a female, ten and a quarter inches in length, in addition to the visceral adhesions, it was observed that the wall of the pyloric section of the gut was abnormally thin and quite translucent. On opening this section of the intestine it was found to contain only a straw-colored fluid of a thick consistency.

Microscopic examination of this fluid under low powers showed that it contained a concentrated culture of a pear-shaped polymas-

tigine protozoan and later study of smears stained by the Giemsa method and examined at high magnifications led to the identification of this parasite as *Octomitus salmonis*. An inspection of the contents of the several regions of the intestine showed that the infection was typical and that the protozoa were most abundant in the region of the pylorus, and although small numbers of the parasite were present in all parts of the small intestine none could be found in the rectum.

The second trout, a specimen eight and a quarter inches in length in which the gonads were undeveloped, was only slightly infected and parasites were found only in the region of the pylorus.

The present specimens of Octomitus agree in morphological and pathological characteristics with the illustrations and descriptions given by Moore ('22) and Davis ('26). Specimens killed and fixed with absolute alcohol and stained by the Giemsa method averaged ten microns in length by four microns at their greatest width. Variation in size was small and ranged only between eight and twelve microns in length. The general form, manner of locomotion and appearance when fresh agree with descriptions given by Moore and Davis while such details as the morphology of the nuclei, the axostyles and the granular masses situated at the posterior ends of the latter are readily discernible in preparations stained as the above.

While the mode of infection of these two specimens is necessarily uncertain, it is possible, from the data concerning the history of the lake and by the determination of the age of these specimens by the examination of scales, to narrow down the source of contamination to a planting of fingerlings made in the fall of 1934, the preceding year.

Prior to this, the last occasion on which fish had been planted in this lake was in 1928. A study of the scales of the larger specimen showed that it was entering its fifth year and obviously could not have been an infected specimen introduced into the lake from an infected source. The same was the case of the smaller specimen which was just beginning its third year. While the data are not really sufficiently extensive, still in the absence of this infection from the other fish examined it seems most logical that this infection is not a natural one in the lake and is to be distinguished accordingly from the other forms of parasitism which have a much higher frequency in the adult trout.

In the fall of 1934 3,000 fingerlings were planted in Lake Edward. These had been obtained from the Ste. Alexis des Monts hatchery, where there is every reason to believe that *O. salmonis* occurs causing large losses of fry.

In the spring of 1935 4,000 yearlings averaging nearly six inches in length were planted in Lake Edward. These had been obtained from a hatchery in Vermont and it is doubtful that these latter fish were infected. Not only had they been transported a long distance

before being placed in the lake, but in addition I had the opportunity of examining eleven of these fish, eight of which were taken within a month following the date they were planted, and all of which gave negative results.

From the above data it seems most probable that the source of the present infection was the fingerlings planted in the fall of 1934 and that the two specimens which were taken and which were infected had been contaminated by some of the fingerlings from that planting.

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POLLUTION BY OIL IN RELATION TO OYSTERS

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The importance of oil well activities as possible polluting agencies in relation with oyster beds was brought sharply to the attention of the Louisiana Department of Conservation in January, 1933, and led to the conduct of certain field and laboratory investigations by the writer, which are herein briefly discussed.

Oystermen reported that oysters were dying in great numbers on the cultivated beds in the neighborhood of relatively recently drilled oil wells. It was frequently noted that even the surviving oysters when culled for market either died in large numbers while temporarily rebedded awaiting marketing or suffered heavy mortality during transportation to market. This mortality attained alarming proportions in many cases, and compelled fishermen to abandon leased beds which they had very successfully cultivated over periods of as much as twenty years or more.

One somewhat puzzling factor became immediately apparent. This was that no spatial relationship existed between the intensity of damage of an oyster bed and the distance of that oyster bed from an oil development. This will be referred to again.

The oil developments involved are of a peculiar type, namely, the exploitation of oil deposits in "salt domes." Salt domes are peculiar geological formations occurring at various depths and may contain, in addition to salt, deposits of oil and of sulphur. Located by geophysical methods, these salt domes are drilled sometimes to considerable depths, even approaching ten thousand feet. When an oil well is brought in on such salt dome, it may show a history of transition from production of oil alone to a constantly increasing proportion of "salt brine." This salt brine, derived from the deep strata, comes to the surface in intimate contact with the crude oil and by various means is separated from the crude oil and discarded. Disposal of this salt brine was carried out previously, in the area concerned, by the simple procedure of releasing it into the sea. It should be mentioned that many of these salt domes, including the ones of importance to the oyster industry, are located in the shallow coastal waters of the Gulf of Mexico.

The writer planned and executed a series of field surveys, field experiments and laboratory experiments designed to discover whether or not the interaction of oil and sea water caused damage to oysters.

These studies fall into three groups. First, field studies in which surveys of oyster beds were made, counts performed to ascertain the proportion of mortality and individual oysters examined for general condition. Water analyses were made at the same time, and samples of substantial mud and other materials were collected to determine if

oil were present. Analyses of sea water samples taken at various places were also performed to ascertain quantities of dissolved salts, amount of oxygen present and concentration of hydrogen sulphide present.

Second, certain field experiments were performed by transporting oysters from thriving beds located outside the area of alleged pollution and planting them on two-story wooden racks one meter in area, the lower rack resting on the substratum, the upper being placed one meter above the substratum. Six sets of such racks were constructed, two sets being used as controls and placed in an area known to be free from pollution. Fifty oysters were placed in each tray. The experiments when examined approximately three months later showed a differential mortality. One experimental planting "setup" on a bedding ground from which heavy mortality had been reported showed a death rate of 46% in the three months, during which period a control "setup" containing a similar number of oysters secured from the same oyster bed but placed outside the area of alleged pollution showed a contrasting mortality of only 9%. These rough field experiments, crude as they were, nevertheless suggested that some influence in the neighborhood of the oil wells was causing damage to the oysters' welfare.

Third, provision was made for marine laboratory facilities involving the establishment in a good oyster area of a temporary laboratory equipped with an automatic electrically driven sea water pumping system. Tanks constructed of wood and glass were used, having, when in operation, an individual capacity of about 30½ meters. The water supply was derived from the immediate natural waters wherein oysters were normally living and were being successfully cultivated. Oysters in these experiments were secured from such cultivated beds in the immediate neighborhood of the temporary laboratory so that apart from any alteration due to pumping or due to experimental modification they were subjected to the water supply in which they had grown. Initially an attempt was made to test out the effects of (a) sea water that had come in contact with crude oil derived from the wells suspected of pollution; (b) oysters subjected to a water supply modified by the addition of small control quantities of "bleed water," the brine that comes up with the oil in the oil wells; (c) the effect of placing oysters on substratum composed of mud obtained from the neighborhood of the oil wells in the area of alleged pollution and containing incorporated in it heavy concentrations of crude oil.

It became early a surmise of the writer that crude oil itself was the important damaging agent, and in subsequent series the efforts were concentrated to determine the effects on oysters of a water supply that had been contaminated by contact with crude oil. Each experimental series was adequately controlled by placing a corresponding number of oysters in a similar tank, under similar conditions of temperature, light, etc., and receiving the same water supply with the single exception that in this instance no artificial pollution of the water was introduced. A highly efficient method of aeration was introduced in the water

supply of each tank to eliminate the effects of abnormally high concentrations of dissolved gases due to the physical effects of pumping under pressure. A careful check clearly demonstrated the complete efficiency of these aerators.

It must be sufficient in this brief statement to indicate that the experimental series gave clear cut differential mortalities. The first experimental series begun on October 20, 1933, showed on February 6, 1934, a mortality of 17% in the controls, contrasting with a mortality of 90% in the oysters subjected to sea water which had come in contact with crude oil. When this series was terminated on March 10, 1934, the mortality in the oysters subjected to the polluted water supply had risen to 100%, while the mortality in the controls remained at 17%. It should be emphasized that the oil itself was not in direct contact with the oysters. The experiment was so arranged that the incurrent supply of sea water fell through the layer of crude oil after which it passed through a series of baffles into the tank. In this way the drops of oil were trapped and prevented from passing into the tank. Such a procedure was found to be highly necessary, since the oil tended to form large, explosive bubbles with oil as the external and water as the internal phases.

A series set up on March 10 and examined on May 9 consisted of one control tank and three experimental tanks. These latter received a water supply which had come in contact with crude oil. At the end of this period the three experimental tanks showed mortalities of 32%, 88% and 94% respectively, an average mortality of 71%, giving thus a sharp contrast with the mortality of only 2% exhibited by the control oysters during the same period. As in the other experiments fifty oysters were used in each tank.

One of the other series of experiments is of special interest since it was conducted during the height of summer weather at which time the temperature range fluctuated from 26° to 31° centigrade. This elevation of temperature, although natural and seasonal, had the expected result of speeding up the effects of substances present. The two experimental tanks showed after a period of only 22 days a mortality of 52% and 84% respectively, an average of 68%, while during the same period the control oysters, subjected to the same water supply but without oil pollution, exhibited a mortality of 16%. The oil was replenished but once (at the end of eleven days) during this experimental series.

The consideration of the ratio of water to oil provides some startling results. In the last experimental series mentioned twenty-five cubic centimetres of oil were used through which an incurrent water supply of 500 cubic centimetres per minute entered and the oil was not replenished for eleven days. In each minute, therefore, the volume of water was twenty times that of the oil with which it came in contact. In each hour the proportion reached one part of oil to 1,200 parts of water. In each day the proportion reached one part of oil to 28,800 parts of water, while in the entire eleven days the propor-

tion reached the remarkable figure of only one part of oil to 316,800 parts of water.

Field investigations have indicated that under the conditions existing along the Louisiana coast oil well activities offer serious possibilities as polluting agents. The relatively shallow inshore areas of the Gulf of Mexico carry characteristically a heavy load of silt. Agitation of the water by currents, by wave action or other factors accomplishes the result that oil floating as films on the surface rapidly becomes incorporated into the substratum. Oil may thus produce its greatest modification of the sea water at varying and not readily predictable distances from the initial source of oil pollution. Carried by surface currents, such oil may come to rest in the substratum at some more or less distant point where it may continue to produce whatever effects are the result of its interaction with sea water.

It would seem to this investigator that the salt water brine originating from the depths of the oil well must itself undergo interaction with crude oil with which it has been brought, in intimate contact, to the surface. Since in a single salt dome as many as 430,000 gallons per day of this "salt brine" have been produced and released into the sea, it would appear inevitable that some significant modifications of the environment must result.

It has been the experience of the Department of Conservation of Louisiana that when commercial or industrial agencies cause damage to other interests through their activities, such agencies, when once convinced of their responsibility, seriously endeavor to eliminate the cause of damage. A most necessary step to secure such cooperation is naturally that convincing evidence be presented to show that the damages alleged are actually due to the causes to which they are ascribed.

The remarkable expansion of oil developments in the Louisiana shallow coastal waters, certain of which developments are situated in the midst of some of the State's most valuable oyster waters, has created a complex conservation problem whose solution demands exacting and exhaustive scientific investigation.

A PRELIMINARY NOTE ON THE FISH POPULATION OF LAKE JESSE, NOVA SCOTIA

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Catt (1934) has presented an account of an experiment which is being carried out by the Fish Culture Branch of the Canadian Department of Fisheries in Lake Jesse, Nova Scotia, where copper sulphate (3.06 p.p.m. of $C_uSO_4.5H_2O$) was added to the waters of this lake on August 3, 1934, in order to destroy the existing predatory fish population. By this means it is hoped that better conditions will be provided for planting brook trout fry as soon as the food organisms have become re-established. I (Smith, 1935) have also given an account of this experiment, dealing more fully with the effect of the copper sulphate treatment upon the flora and fauna of the lake, and this additional note presents a short study of the fish population, as estimated from the number of fish that were killed.

A certain number of fish evidently survived, either through a specific resistance to, or evasion of, the full dosage of copper sulphate. During the week following the treatment a number of killifish were seen at the outlet from the lake, and one white perch and two yellow perch were taken by gill-netting and seining. In early May, 1935, extensive fishing with line-trawl and gill-net yielded two eels. However, in view of these findings we have concluded that the number of fish that did survive constituted a very small proportion of the total population.

It was found that almost all the fish killed came into the marginal zone of the lake and could be secured by wading. An examination of the bottom in the deeper water with the aid of a water-glass revealed very few fish. This condition made it comparatively easy to estimate the total fish population, as based on the number of dead fish found over several areas about the lake shore. Actually the fish found over one-eleventh of the shore-line were enumerated. Also a sample was preserved. This sample was composed of all the fish, except eels and catfish, found on several smaller areas around the lake, and was a random sample. In the case of the eels and catfish the means available for preservation of the fish permitted only a small sample, which was also a random one. A careful search was made for brook trout, since it was of particular interest to determine the number of this species existing in the lake.

The data obtained are presented in Table on top of next page.

By the means of estimation the total fish population killed was 33,025 individuals. Numerically the yellow perch predominated, totalling 14,177, with the killfish next with 10,098. The number of white perch was 5,781. Thus, the two species of perch, which may be considered as both competitors and predators in relation to brook trout, made up 57 per cent of the population. The detrimental effect of the dominance of these two species is probably reflected in the

TABLE 1.—NUMBER AND WEIGHT OF FISH KILLED IN LAKE JESSE

Species	Number	Weight Grams	Weight Pounds	Number in sample for weight	Lbs. per acre
Salvelinus fontinalis (Brook trout)	29	7,911	17.4	5	0.4
Notemigonus crysoleucas (Golden shiner)	2,611	41,227	90.9	111	2.0
Semotilus atromaculatus (Creek chub)	22	—	—	—	—
Catostomus commersonnii (Common sucker)	22	—	—	—	—
Ameiurus nebulosus (Catfish or bullhead)	1,179	104,342	230.0	21	5.1
Anguilla rostrata (Eel)	1,095	13,362	29.5	29	0.7
Fundulus diaphanes (Killifish)	10,098	31,910	70.3	325	1.6
Perca flavescens (Yellow perch)	14,177	93,006	205.0	497	4.6
Morone americana (White perch)	5,781	113,308	249.9	229	5.5
Pungitius pungitius (Nine-spined stickleback)	11	—	—	—	—
Totals	35,025	405,066	893.0	1,224	19.8

small number of brook trout found in the lake, namely 29. Furthermore, the trout taken averaged a little over half-a-pound in weight; there were no fry or fingerlings, although there was opportunity for natural propagation. Only one stickleback and two each of the suckers and creek chub were found in the areas over which the fish were enumerated.

The weight of the fish was secured after they had been preserved in formalin. That of the suckers, sticklebacks and creek chub was not considered, as they did not occur in the areas from which the sample was preserved. The estimated total weight of fish was 893 pounds, which gave a standing crop of 19.8 pounds per acre. (Lake Jesse has an area of 45 acres.)

This poundage of fish per acre seems at first glance surprisingly low. However, we are dealing with wild or uncultivated waters. As to the amount of fish that can be produced under cultivated conditions we have certain data presented by Langlois (1935). At the Ohio State Fish Farms, 1,299 pounds of smallmouth black bass per acre have been grown. This yield is about 65 times that determined for Lake Jesse. We are perhaps prone to make comparison with cultivated land. Probably a more just comparison between land and water production is that made by Birge (1920)). He has roughly compared the crop of deer in Wisconsin with that of fish from Lake Michigan. He says (p. 189): "We are wholly safe in saying that the lake produces ten times as much food as does the forest, and that from this point of view the lake's performance is a very creditable one."

A determination of the standing crop of fish in a lake, and the relative numbers of each species of fish, has decided value from a fish culture viewpoint. By quantitative determinations of the crops of plankton, bottom fauna and fish of lakes and streams, it would probably be possible through a study of either of the first two to ascertain within limits what amount of fish a body of water will support. This obviously involves extensive studies, and in the case of our work at Lake Jesse neither time nor means permitted such complete observations. Nevertheless, since this line of attack appears to be so fruitful, and since the copper sulphate treatment permits obtaining an integral part of such data, while at the same time combining a practical experi-

ment with one of more theoretical interest, it is hoped that fish-culturists and limnologists elsewhere will try out this method.

The data secured from Lake Jesse also disclosed a condition which probably obtains in many of our lakes. Fishermen have discriminated in their catch with the result that competitor and predator fish have gained the upper hand over trout and other game fish, and since a lake will support only so many fish, it has become difficult to stock successfully and establish game-fish. This condition indicates that more stress should be placed upon experiments designed to create in such lakes a better habitat in which to plant desirable fish.

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TROUT FEEDING EXPERIMENTS WITH NATURAL FOOD (*GAMMARUS FASCIATUS*)

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Previous quantitative studies of the natural food requirements of trout are unknown to the writer. There is nothing particularly unusual in this because collection of material to carry on such a study is by no means an easy task. The purpose of this study has been to partly close the gap in knowledge which exists between our quantitative stream bottom studies and the actual natural food requirements of trout. It will probably be several years before this gap can be satisfactorily filled. Complicating problems stand in the way, such as the determination of the actual availability of the bottom animal foods to the fish and the amount of summer dependence of trout upon terrestrial insects.

The first work of the writer on this subject was during 1933 principally with the fresh water sow bug, Asellus. The error in weighing Asellus was found to be quite large and variable and the result obtained of about 11.86 pounds wet weight of food required to produce a pound of trout was felt to be somewhat excessive. Consequently, during the fall of 1934 it was decided to initiate a new experiment using the fresh water amphipod, *Gammarus fasciatus*.

METHODS

On October 9, 1934, four brook and four rainbow trout fingerlings were placed in separate compartments of equal size, in an upper hatchery trough twelve feet long, 13.5 inches wide, and eight inches deep. Each fish was marked so that an individual record could be kept of its growth, color changes, etc. They were marked by cutting off the right ventral fin of one, the left ventral fin of a second, the adipose fin of a third, while no fins were removed from the fourth fish.

Collections of *Gammarus* were made from our experimental stream at Leesburg, Virginia, and placed in a trough. The collections usually contained other organisms such as caddis, mayfly, and parnid beetle larvae. However, within a day or so these organisms disappeared from the trough where the *Gammarus* were held. The small mayfly nymphs of *Beatis* and parnid larvae worked through the screen at the lower end of the trough, while the larvae of Hydropsyche concealed themselves on the bottom of the trough wherever they could find a convenient place. These rather unusual circumstances made it possible to use *Gammarus* alone in these feeding experiments.

The following technique was used in weighing them: they were removed from the trough with a small net of bobinetting and allowed to drain for one minute. The net with organisms was held for another

minute on blotting paper. The position of the net on the blotting paper was changed three times (every twenty seconds) to facilitate rapid removal of excess water.

The fish were fed these organisms whenever the supply present in the trough became low or exhausted. There were a few days during the experimental period when it was not convenient to collect the necessary food organisms. The number of days without food are recorded in Table 2. From time to time random samples of 1,000 individuals were taken from the collections and weighed. These figures (Table 1) were used in calculating the number of *Gammarus* actually consumed by the fish during the experimental period. The experiments were conducted at a temperature of 54° F.

TABLE 1.

Wet Weight of 1,000 *Gammarus*

	Grams
October 9, 1934	16.35
November 15, 1934	16.23
November 24, 1934	19.44
January 19, 1935	13.33
January 31, 1935	16.50
February 27, 1935	21.50
Average	17.23

Results

The growth curve of each fish over a five month period is depicted in Figures 1 and 2, while the actual growth data and increases in weight in per cent are shown in Table 3. The total number and wet weight of *Gammarus* consumed by each lot of four fish is shown in Table 2. During the five month period, an average wet weight of 481.93 grams or 27,971 individuals were fed to each brook trout, while 452.5 grams or 26,263 individuals were fed to each rainbow trout. With the brook trout, 6.05 grams of food (wet weight) were required for each gram increase in weight. In other words, 6.05 pounds of food (wet weight) were required to produce a pound of brook trout; rainbow trout required 6.63 grams to produce a gram of trout (6.63 pounds per pound of trout).

TABLE 2.—QUANTITY OF *GAMMARUS* FED IN GRAMS (WET WEIGHT)

	(Brook trout)			(Rainbow trout)		
Period	Monthly total grams	Estimated No. of individuals	No. of days without food	Monthly total grams	Estimated No. of individuals	No. of days without food
Oct. 9-Nov. 9	262.50	15,235	1	236.00	13,697	0
Nov. 10-Dec. 9	303.15	17,594	3	252.00	14,626	0
Dec. 10-Jan. 9	354.25	20,560	3	361.00	20,952	3
Jan. 9-Feb. 8	457.83	26,572	5	415.00	24,086	7
Feb. 9-Mar. 9	550.00	31,921	1	546.00	31,689	1
Totals	1,927.73	111,882	13	1,810.00	105,050	11

TABLE 3.—GROWTH DATA ON TROUT FED *GAMMARUS FASCIATUS*

(Brook trout)

	Length in inches	Initial weight Oct. 9, 1934 (grams)	Nov. 10 (grams)	Dec. 10 (grams)	Jan. 10, 1935 (grams)	Feb. 9 (grams)	March 9 (grams)	Total per cent increase weight	Length of fish at end of experiment	Per cent increase in length
No. 1	4.92	20.0	30.0	43.5	71.5	95.0	109.0	445.0	8.0	62.6
No. 2	5.32	23.5	33.0	49.0	69.0	92.0	112.0	376.6	8.25	55.1
No. 3	5.04	19.0	32.0	44.0	64.0	85.0	100.0	426.3	8.00	58.7
No. 4	5.00	22.0	36.0	48.5	61.8	73.0	82.0	272.7	7.25	45.0

(Rainbow trout)

	Length in inches	Initial weight Oct. 9, 1934 (grams)	Nov. 10 (grams)	Dec. 10 (grams)	Jan. 10, 1935 (grams)	Feb. 9 (grams)	March 9 (grams)	Total per cent increase weight	Length of fish at end of experiment	Per cent increase in length
No. 1	5.4	30.0	41.0	53.0	55.0	80.5	97.0	223.3	7.75	43.5
No. 2	4.88	23.0	32.0	43.0	65.5	66.0	84.0	265.2	7.13	46.1
No. 3	4.60	13.0	22.0	31.0	42.5	51.0	67.0	385.7	6.50	41.3
No. 4	3.92	11.0	19.0	31.0	51.0	70.0	102.0	827.3	8.00	104.1

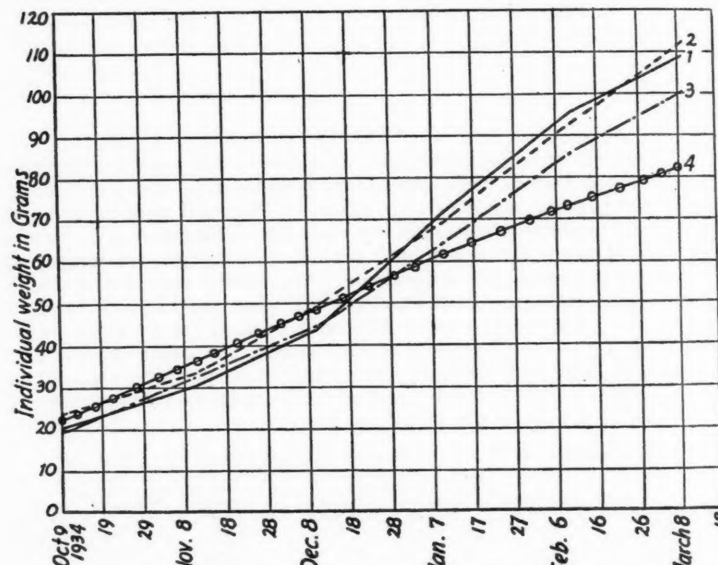

Fig. 1 Growth of Four Brook Trout on Gammarus at 54°F.

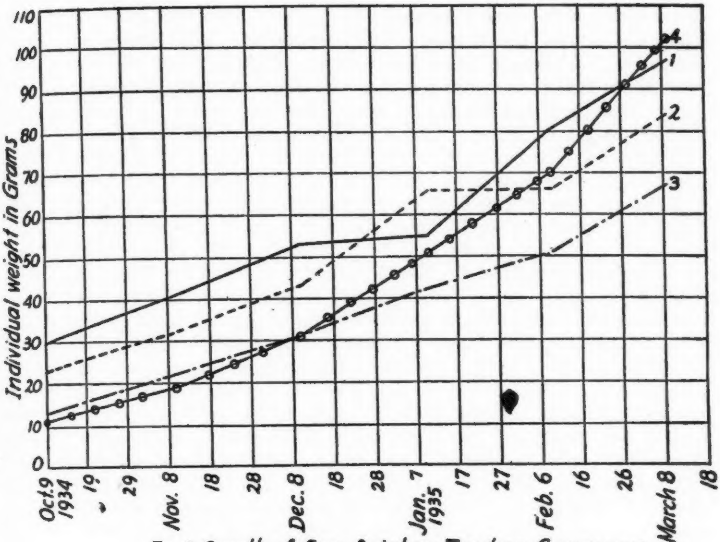

Fig 2. Growth of Four Rainbow Trout on Gammarus at 54 °F.

It has been estimated from bottom fauna studies conducted in an experimental stream at Leesburg, where the *Gammarus* for this study were collected, that the dry weight of *Gammarus* is 19.3 per cent of the wet weight. This fact, which has been determined from a large number of samples, enables us to put the data on a dry basis if desired.

Availability of the natural food in a stream presents one of the main obstacles in using such data as have been gathered for computing the maximum stock intensity when the food producing capacity of the stream is already known. The following experiment will illustrate this point:

On November 24, 1934, the four brook trout which had been feeding on *Gammarus* since October 9th, were transferred to a trough section of the following dimensions: 31.5 x 13.75 inches (area 435 square inches). The section had previously been prepared for them by placing 39.25 pounds of gravel in the approximately three square feet of space. The gravel used was from the same stream in which the *Gammarus* were collected. 2,104 *Gammarus* were placed in this compartment, and within a few minutes all but one individual had concealed themselves among the gravel. At 2:30 P. M., four brook trout were placed in the three square foot section and at 2:30 P. M. on the fol-

lowing day they were removed. The gravel then was gone over carefully to remove the unconsumed Gammarus. 2,005 individuals were recovered. Although the daily capacity of these trout about this time was about 600 *Gammarus* per day (for the four fish), only ninety-nine were consumed and there is a possibility that a few individuals were ground to pieces in retrieving the *Gammarus* from the gravel.

The color changes in the fish during the experimental period were also noted. By November 8th, two of the brook trout were highly colored and one rainbow showed a marked pink stripe along its lateral line; on November 10th when the fish were weighed, each fish was arranged according to its color. At that time No. 4 brook trout was most highly colored, while No. 2 ranked next in color, Numbers 3 and 1 were about the same, rather poorly colored, but both had red spots. On November 10th, No. 3 rainbow trout was most highly colored, No 4 next, and Numbers 1 and 2 rather poorly colored. The color rank of Numbers 4 and 2 brook trout was maintained throughout the experimental period. No. 4 was a male fish. Numbers 3 and 4 respectively were most highly colored of the rainbow trout during the experimental period, but third and fourth places in color rank interchanged as little difference could be noted. The most highly colored rainbow trout was a male also. These fish reached a degree of brilliance in color never obtained by other hatchery fish and few wild fish that the writer has seen.

Summary

Two lots of four brook trout and four rainbow trout each were fed the fresh water amphipod, *Gammarus fasciatus* for a period of five months. The amount of food fed and the growth of the fish were noted. From this data, the amount of natural food required to produce a pound of trout was calculated. It was shown that 6.05 pounds (wet weight) of *Gammarus* were required to produce a pound of brook trout, while 6.63 pounds (wet weight) were required to produce a pound of rainbow trout. It was estimated that 111,882 *Gammarus* were fed to the brook trout during the five-month period, while 105,050 were fed to the rainbow trout.

THE FEEDING OF TROUT IN CALIFORNIA HATCHERIES

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For the last three years, California has been undergoing a very interesting evolution in respect to many of its trout cultural problems. Progressive evolution has been especially marked in the methods of feeding and in the types of food.

For two years, the writer, ably assisted by Mr. R. C. Lewis, has been conducting a large series of experiments in a special experimental hatchery with the purpose of improving the types of food and the methods of feeding. It would not be advisable to go into detail at this time. Those interested in learning more of our results should see the "Progress Report of Trout Feeding Experiments," by J. H. Wales and R. C. Lewis.* A report of the second year's experiments will be published shortly.

There can be no question but what beef liver and beef heart are good trout foods. These have been used almost exclusively in California in feeding fingerlings. However, we have shown clearly that there are several dry meal supplements which will not only reduce the cost of the food, but will produce larger fish and ones which are just as healthy as those fed entirely on heart or liver.

This fact has been known for several years. A number of investigators have carried out feeding experiments similar to ours. However the California hatcherymen are much more easily convinced by trials performed at home than by those of which they read. In addition there were certain points brought out in our experiments which have not been clearly demonstrated by previous workers.

The most important substitutes which we have used are abalone meal, salmon egg meal and dry milk meal. The last two are abundant and cheap enough to make them valuable trout foods. The best combination which we have found is composed of thirty per cent beef liver, thirty-five per cent egg meal and thirty-five per cent dry milk. These percentages are in respect to the natural weights. The two meals can be stirred into the ground liver by hands, or put through a grinder. Some water should be added so that after soaking for about two hours, the meal will be soft.

It has frequently been said that fish should be at least two inches in length before beginning to feed meals. However in California the fingerlings do not average two inches when planted so that if one is to use meals he must start early. In our experiments to date, we have started our fish on the same foods that were fed throughout the experiments, but hereafter, it would seem advisable to feed straight beef heart until the fish weigh about 125 per ounce then change to the

*California Fish and Game, Vol. 21, No. 2, pp. 110-124.

combination. Our results show that very young trout thrive best on straight heart, but that later on the combination is much superior.

In our 1934 experiments we found that Brown trout could be grown for twenty-four cents a pound on the combination above, whereas it cost thirty-five cents to grow a pound of Brown trout on beef liver alone.

In our 1935 experiments we found that it cost twelve cents to raise a pound of Brook trout on this combination of liver, salmon egg meal and dried milk, as compared with sixty-three cents a pound using straight beef heart. The costs per pound of the foods mentioned were: beef heart, thirteen cents; beef liver, eleven cents; salmon egg meal, seven cents; dried milk, six and one-half cents.

We do not maintain that these costs cannot be improved, but they are indicative at least of the important saving which is possible.

The primary object in these feeding experiments was to study the relation of foods to the health of the trout. In no way does the combination of the meal with liver adversely affect the health except in young Rainbow fingerlings whose gills are irritated by pollution with the meals. This irritation can be obviated by starting with straight heart as previously stated and later changing to the meals. Otherwise the fish produced on the liver, salmon egg, and dried milk diet were every bit as healthy as those grown on straight liver, and much better than those fed continually on heart.

We found that in a general way the health of the fish was not dependent upon the type of food as much as upon the way in which the food was fed. From an administrative standpoint this is a deplorable fact, because it is much easier to see that any particular food is used than it is to see that it is fed correctly. In a certain case a hatchery man used a particular diet which we had found in our experimental hatchery to be exceptionally good. The results which this hatchery man had were quite different from ours and the only reason was that the food had not been fed in the same way. Once a desirable food has been found, the results, good or bad, must be correlated with the way it is fed.

The progressive evolution mentioned at the beginning of the paper can best be illustrated by describing briefly the feeding methods. Until about three years ago, the way a State hatcheryman fed his fish was largely his own private affair. He might use a screen bottom dipper, or he might simply pour it into the water from a ladle. When feeding liver, he almost always mixed in considerable water and then beat this diluted mixture into a thin soup. Naturally such a food was extremely easy to feed, but that was its only good feature. It was very wasteful and it made it very difficult for the fish to breathe and at the same time obtain a sufficient amount to eat. The food was seldom distributed properly and underfeeding was the rule. Such a situation naturally fostered disease on no uncertain scale. Feeding was greatly improved when each of our twenty-five hatcheries was provided with

a set of dippers each having its bottom perforated by different sized holes. When the fish were very young they were fed through a No. 1 dipper, when somewhat larger, through a No. 2 dipper, etc. Each size of fish being provided with a special dipper. This system, of course, does not keep some individuals from diluting their liver with water, but it has provided the conscientious hatchery man with a good tool. If one is feeding beef heart through these dippers it isn't important to feed it undiluted except that when mixed with water, it sometimes comes through the holes too fast and does not permit an even distribution. Closely connected with this point is the important fact that heart can be ground finely and still not become partially liquified as is the case with liver. For this reason heart is a good clean food, especially valuable for very young fish. Heart can be fed properly at a much greater speed than liver.

As has been said, the dippers now in use throughout the California hatcheries are distinctly better than the spoon or ladel previously used. However, in looking ahead, one naturally sees that the next step toward the perfect food dipper is to discard the "gravity type" in favor of a "force dipper." In the customary dipper the food comes out through the holes at the bottom due to its own weight. When the dipper is full the weight of the food pushes it out through the holes in good shape but as the weight is diminished it is necessary to wash the food from the dipper by violent shaking. This breaks up the particles and causes waste and undesirable fouling of the water.

One of the hatcherymen in this state has devised a dipper which to us is entirely new. It resembles the usual dipper except that the sides are straight and it is provided with a plunger which pushes the food out through the holes. It differs from a potato ricer in that the holes are only at the bottom and the handle is hinged at its distal end and permits operation with one hand. The details of its construction will undoubtedly be modified considerably. A relatively stiff food can be fed through this dipper with as much speed as a semi-liquid food can be fed through the gravity type. The food is forced out in discrete particles which do not break up quickly. It is therefore possible to use very fine grades of meal even for large fingerlings without having them separate in the water and be wasted. Fish have a tendency to reject large particles of meal but when fine meals are bound by well ground liver into suitably sized particles the fish cannot help but take them.

Controlled experiments with this type of dipper are anticipated for the coming season.

We are also experimenting with a new food for adult trout. The present one, we feel, is nutritionally deficient, easily broken up in the water and consequently wasted. We have begun experiments to determine the value of a combination of several good meals with liver. This mixture is ground out through a large plate of a grinder in such a consistency that it remains in discrete particles similar to short

lengths of spaghetti, suitable for the adult fish and yet not too hard to be palatable.

One hundred adult Brown trout whose total weight was 780 ounces required 24 ounces of this meal combination a day at a cost of nine cents per pound or thirteen and one-half cents per day. A control lot of Browns weighing the same required 56 ounces of heart and liver a day. The cost of this food was about fifteen cents per pound making their food cost about 52 and one-half cents per day.

Discussion

Mr. Wales: I may say that we have given up speaking of fish in terms of length and speak entirely of the fish as so many going to the ounce, which naturally you can translate very easily into length from a curve. It is extremely accurate and handy for the hatchery man. If when you go into a hatchery you say: "Well, how many of these fish go to the ounce?" he will say thirty-five or ten or whatever it may be, and you immediately have an idea what the gain in weight has been, which is the most important factor. It is not how much they gain in length that is the important thing; it is what they gain in weight, because after all if you are feeding a certain type of food you are speaking of the food in pounds, not in yards.

During the last two years the state has made it necessary for the hatchery to use a special type of dipper, with a tin bottom, perforated with different sized holes, one size of hole to be used when the fish are small and another size to be used when the fish get larger. That is a good method, but it has certain disadvantages which I would like to point out. When you start to feed from a dipper of that sort it is all right at first because the weight of your food in your dipper will force the food through the holes in good shape, but as the food is used up it is necessary to wash the food out of the dipper by washing the dipper back and forth in the water, which has the effect of breaking up the particles. One of our hatchery men devised a type of dipper which is similar to a potato ricer but has holes only at the bottom, and the handle is hinged at its distal end so that you can operate the dipper with one hand. We are going to run an experiment with that type of dipper next year as compared with the old type. I feel certain it is going to mean considerable saving both in money and in the health of the fish, because the food can be forced out at an even rate from the time you start to feed a dipperful until you finish that dipperful, and the food is always brought out through the holes in definite particles without the necessity of washing the food out and the consequent breaking up of the particles. As a matter of fact I have one of these dippers with me; it is not here at the moment but if anyone is interested I should be glad to bring it up to the room this afternoon and let him see it.

PROPAGATION OF SMALLMOUTH BASS IN TROUGHS AT SOUTH OTSELIC BASS HATCHERY

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An experiment was conducted at South Otselic during the 1935 season to determine the advisability of rearing smallmouth bass in troughs. The purpose of this work was to establish definite information concerning each of the following questions.

First—Is it practicable to rear smallmouth bass in troughs as in trout culture?

Second—What amount of food do bass require in relation to body weight?

Third—What are the dietary requirements of bass fingerlings?

Fourth—Can the mortality be controlled to a degree comparable with that in trout culture?

The fry for this experiment were put in a half acre pond well stocked with Daphnia. When this pond was drained twenty-seven days later seventy-eight per cent of the fish had survived, weighing about 850 to the pound (see Table 5). These fish were put in nursery troughs having a water capacity of nine and one half cubic feet with six to eight gallons of water per minute passing through them. For the first five days they were fed on ground carp, which they immediately took, until the experimental diets were given.

The bass were cared for the same as troughs of trout. Disease treatments were given to all the troughs at the same time. The salt treatments seemed to have little effect on controlling the high mortality which occurred at the end of the second week. The fish stood a three per cent salt bath for twenty minutes at 62° F. and they stood potassium permanganate at a concentration of 1:50,000 for thirty minutes with the water supply shut off. This latter treatment reduced the mortality which apparently was caused by a bacterial infection that manifested itself by whitish patches on the head or about regions of the dorsal, anal, or caudal fins.

The fish were fed six times a day with a feeding dipper. When carp was used as a food the fish would consume approximately thirty per cent of their body weight per day, whereas using carp and twenty per cent dry skim milk they would take only twenty-five per cent. The amount of food to be fed each day was set down at the beginning of the week, and it was planned to feed half the fish an excess of their requirements and the other half about what they would eat. Therefore the amount of food consumed was governed by the type of diet and the water temperature. For these reasons there was often much food left in the troughs which influenced the conversion. With an average water temperature of 68.9° F. for the six weeks it is estimated that the fish

ate about fifteen per cent of their body weight per day when the ground fish was supplemented by twenty per cent dry skim milk.

At the beginning of the experiment the fish ate the carp better than the herring but after the first two weeks the preference was reversed. Those lots fed herring seemed more active and healthier than those on carp whether these meats were used alone or with one or two dry supplements. This point is substantiated by the mortality for each lot given in Table 5. This same table tends to show that one supplement, dry skim milk, improved the ration in either the case of carp or herring but one could only say that by the addition of a second supplement, namely cottonseed meal, the diet cost was reduced. It is well to note the drop in mortality in Lot Nine when changed from carp with twenty per cent milk to herring with twenty per cent milk and twenty per cent cottonseed meal. On checking the result at the end of the third week, it was decided that the meats alone in the first four lots did not constitute a balanced ration. Therefore the two dry supplements were added to compare with the cases where one supplement was used. After the first week on the new diets an improvement was noticed in the fish.

The following tables furnish the complete data for the experiment:

DATA

July 13 to August 23, 1935

TABLE 1

COMPOSITION OF DIETS

Diet A	100% Carp
Diet B	100% Herring
Diet C	80% Carp, 20% Skim Milk
Diet D	80% Herring, 20% Skim Milk
Diet E	60% Carp, 20% Skim Milk, 20% Cottonseed Meal
Diet F	60% Herring, 20% Skim Milk, 20% Cottonseed Meal

TABLE 2

DIET FOR EACH WEEK WITH AVERAGE PER CENT OF BODY WEIGHT FED PER DAY

Week	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
First	A 21.3	B 21.	A 31.1	B 32.2	C 21.3	D 20.6	C 30.2	D 31.	A
Second	A 26.2	B 26.7	A 32.8	B 31.5	C 25.2	D 26.2	C 30.	D 30.8	A 42.
Third	E 25.2	F 20.9	E 31.8	F 26.2	C 25.8	D 24.4	C 31.4	D 30.7	C 31.9
Fourth	E 21.	F 20.6	E 25.7	F 26.4	C 27.	D 26.4	C 28.8	D 28.3	C 30.8
Fifth	E 20.2	F 20.1	E 24.5	F 24.6	C 24.8	D 24.	C 25.6	D 24.1	F 26.
Sixth	E 20.1	F 20.	E 25.4	F 25.	C 27.2	D 25.2	C 21.7	D 20.	F 25.3

Note: 1. Letters refer to diets in Table 1.
2. Numbers refer to per cent of body weight fed.
3. Diets changed in first four lots at end of second week.
4. Diet changed twice in Lot 9.

TABLE 3

GRAMS FOOD FED PER GRAM GAINED

Week	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
First	12.81	11.49	12.92	20.75	14.3	7.2	9.49	11.97	
Second	15.2	20.9	34.	22.6	8.75	12.55	12.	12.	19.
Third	*	10.7	*	11.07	7.66	6.06	15.	11.75	10.2
Fourth	10.	9.9	16.7	16.	13.7	19.9	13.4	14.4	16.1
Fifth	9.	10.8	7.5	10.6	12.1	8.2	11.2	8.4	14.1
Sixth	10.1	10.7	14.14	13.8	37.	16.	35.8	12.3	18.6
Average	11.43	12.42	17.05	15.8	15.59	9.99	16.15	11.82	15.6

Note: 1. Conversion is not accurate as an excess of food was used.
2. Pond data averages nine grams of food to one gram gained.
* Omitted due to mortality.

TABLE 4
WEIGHT AND GAIN
Weight per fish (grams) and gain for period

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
Start	.508	.539	.555	.527	.531	.511	.523	.555	.51
End	.991	1.154	1.135	1.152	1.292	1.44	1.268	1.507	1.19
Total % Gain	95.	114.1	104.3	118.8	143.	181.8	142.5	171.8	133.3

Per cent gain per week

Week	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
First	12.	13.4	18.5	11.6	13.	22.3	25.	19.8	12.1
Second	13.5	9.85	6.98	10.7	21.8	15.7	19.9	19.6	16.8
Third	2.47	12.78	1.75	17.95	27.2	32.35	15.7	19.9	24.25
Fourth	17.3	16.7	11.17	12.2	14.9	9.7	16.5	15.2	14.45
Fifth	17.05	15.	26.05	17.5	15.	22.95	14.7	22.03	13.7
Sixth	14.6	14.	13.3	13.8	5.2	11.5	4.5	12.5	10.

Note: 1. This table gives per cent gain at end of each week over preceding week.

TABLE 5
NUMBER AND MORTALITY
Number of fish used and total mortality

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
Start	2496	2494	2495	2492	2499	2500	2495	2498	2836
End	1154	1758	1052	1626	1262	1812	1746	2012	1406
Total % Mortality	53.8	29.5	57.8	34.7	49.5	27.6	30.	19.5	50.5

Per cent mortality per week

Week	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
First	3.33	1.6	3.45	4.25	3.48	4.24	4.14	3.4	10.8
Second	5.53	5.46	7.65	3.6	5.12	7.6	3.07	6.9	9.28
Third	40.4	20.6	43.8	23.3	26.6	13.9	8.33	5.96	19.3
Fourth	8.8	3.56	7.1	5.95	11.71	4.2	6.87	3.8	17.5
Fifth	4.74	1.3	6.9	1.78	5.7	.61	4.1	.4	8.75
Sixth	2.53	.4	3.31	.37	10.04	.06	8.2		

Note: 1. Fish were treated at end of third week with potassium permanganate which affected the mortality in the fourth week.
Note: 2. Mortality is less on herring than on carp diets in all cases after end of second week.

Conclusions

First—The question, "Is it practicable to rear smallmouth bass in troughs?" is a debatable one. At South Otselic one would say that it is not from these data as we get greater growth and survival in ponds.

Second—The data presented do not show the amount of food bass required in relation to body weight as all the food given was not consumed. However, as is stated in the text, this varies with the temperature and the type of diet. It is estimated with an average water temperature of 68.9° F. the fish require fifteen per cent of their body weight.

Third—The dietary requirements of bass fingerlings are brought out by the mortality and gain tables for period. They show that herring is better than carp and either one is improved by the addition of dry skim milk.

Fourth—In this experiment the mortality was not controlled comparably to that in trout culture. The mortality is even excessive when the high loss of the third week is omitted.

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A CHEAP, ADJUSTABLE FISH GRADER

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Most hatcheries do not grade trout sufficiently often to prevent considerable losses due both to cannibalism and to promiscuous nipping of fins of smaller trout by larger fish. Where trout are kept in rearing ponds, whether on natural or artificial food, it is essential that large, fast-growing fish be separated from their smaller, slower growing brothers and sisters every few months if any fair percentage of survival is to be attained. Likewise in many western hatcheries where trout are often reared to planting sizes in hatchery troughs alone, more frequent and careful grading would reduce losses considerably and more than repay the efforts involved. Fish culturists rearing selected strains of rapid growing, domestic brood stocks have long used fish graders to separate out their best, fastest growing fish.

Most of the devices used both in this country and Europe usually consist of one or more shallow boxes with parallel rods or bars permanently spaced in the bottom and in which fish are dumped for grading. The smaller swim through while fish too large to get between the bars are held inside the box. The disadvantages of these types of graders are their lack of flexibility, three or four separate grading boxes being required to sort fish into three or four different size groups.

The major problem involved in design of any adjustable fish grader is how best to build it so spacing of rods may be quickly changed for sorting fish of varying ages.

Cook (1932) described an efficient, adjustable fish grader in use in Michigan hatcheries. In this box, made of dow metal, spacing of the bars is regulated by raising or lowering, by means of a hand-screw, tapering pieces that fit in between each rod. The only objection to this box is its high cost running from sixty-five to seventy-five dollars.

Adjustable spacing of rods in the grader designed by the writer is made possible by means of a single pair of removable, milled, brass combs into which the ends of the rods fit at each end of the grader. One edge of each comb is milled for one-eighth inch, and the opposite edges for one-quarter inch, spacing of rods. (See Fig. 1). Then, with but a single pair of combs, and by removal of every other rod, or every two or three rods, as the case may be, seven separate spacings of the rods are possible. It generally requires from three to five minutes to change the spacing of the bars though with experience it can be done in much less time.

The approximate maximum size fish that will pass through the bars when using any of the seven adjustments available with a single pair of combs are as follows:

Size of Fish	*When Using*
1.0 inch	one-eighth-inch comb, all bars in place.
2.0 inches	one-quarter-inch comb, all bars in place.
3.5 inches	one-eighth-inch comb, every other bar removed.
5.5 inches	one-quarter-inch comb, every other bar removed.
6.0 inches	one-eighth-inch comb, every two bars removed.
8.5 inches	one-eighth-inch comb, every three bars removed.
9.0 inches	one-quarter-inch comb, every two bars removed.

The above data was determined by plotting a curve of greatest width of fish as against total length from a large number of specimens. The resulting relationship is shown to be practically a straight line and theoretically at least, while no fish over one inch, for instance, should pass through when the rods are at one-quarter inch spacing, actually they do. Such factors as number of fish placed in grader, size and condition of fish, and length of time they are given a chance to swim down through the rods, all effect the sorting efficiency of the box.

This type grader in use at the Hot Creek Experimental Ponds in California has the curve of width against length in inches of trout plotted on heavy paper and permanently glued on the side, and painted with shellac to show the best spacing to use in relation to size of fish to be graded. Here it can be conveniently referred to as necessary. (See Fig. 2).

Materials and Measurements of Grader

Outside measurements were twenty inches long by twelve inches wide; depth, seven and five-eighths inches. This size permitted its use in standard hatchery troughs though a large box would speed up grading operations in ponds or raceways considerably. Material used was one inch redwood stock which was sufficiently buoyant to float the box about one-third out of water, a very handy feature when grading in ponds. (Fig. 2).

Thirty-three stainless steel rods, three-sixteenths diameter, each nineteen and one-half inches long are required for a grader of the above size. Brass is used throughout in fittings to avoid corrosion by water. Brass handles should be used on the ends of the box rather than hand-holes as fish frequently jump through the latter.

Each comb was ten and three-eighths inches long by two inches wide and made of three-sixteenths diameter brass, milled, as noted above for one-quarter and one-eighth inch spacing of rods on the sides. (Fig. 1). Grooves on the inside of each end of the box provide for insertion and removal of combs. Combs are held firmly down against rods by two small bolts passing through them and the ends of the box to wing nuts and washers on the outside.

Grading rods rest on two, inch-width brass angles under the bottom edge of each end. These are riveted to angle supports screwed to the outside of each end. (Fig. 1). These brass angles, aside from

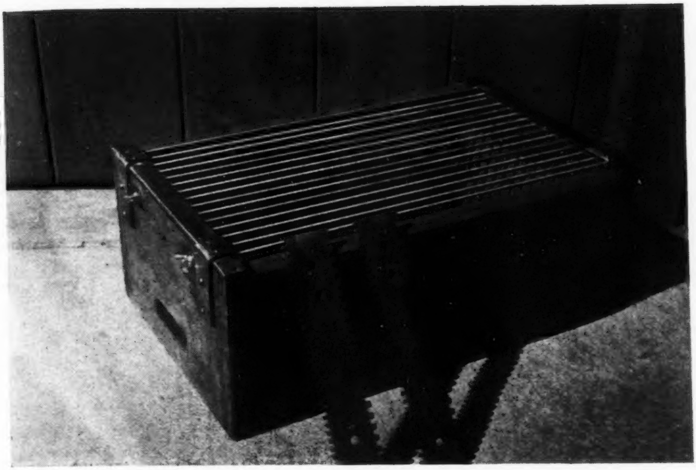

Fig. 1.—Bottom view of fish grader and side view of extra pair of combs.

Fig. 2.—Sorting trout in raceway with grader.

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supporting downward pressure of combs and rods themselves, prevent rods from sliding out at the ends. A space just sufficient to permit insertion of the rods is left between bottom edge of the box and the brass angle supports. Rods are inserted or removed as necessary from one side of the box only. Screws through the opposite side of each angle support prevent rods from rolling out in changing setting of bars. The cost of this type of grader will usually run between eight and twelve dollars. The box itself can easily be built by anyone handy with tools though the milled combs and brass angle supports will usually have to be made in a machine shop.

In conclusion, one improvement in the grader herein described is suggested. The combs might well be fitted to the outside of the ends rather than inside by merely fastening the brass angle supports over the sides rather than on the ends. This would make changing spacing of rods somewhat easier and quicker. The further advantage would be that there would be no rough edges of the combs on the inside of the box upon which fish might possibly injure themselves in grading operations though no such injury has been observed in grading of various sizes in both hatchery and pond operations to date. The rods would then have to be inserted or removed by turning them slightly cross-wise of the box and sliding them under the edges of the angle brass supports.

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PROGRESS OF STREAM IMPROVEMENT IN NEW YORK STATE

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It is generally recognized that the production of wild life is dependent upon the suitability of environmental conditions and that control of these conditions offers a sound basis for increasing production. Control of environmental conditions for the purpose of increasing fish life has been termed stream and lake improvement in the discussions of this method of fisheries management which have been a conspicuous feature of the last few meetings of the American Fisheries Society.

While the basic ecological principles are relatively simple, their application to the numerous and diverse waters offers an almost infinite number of complex problems of applied ecology. Progress depends upon investigation, to determine what various bodies of water need, how (if at all) these needs can be met, and upon the execution of the work, its efficiency in accomplishment of whatever modifications are intended.

Under conditions of intensive management, as on many private estates, some forms of stream and lake improvement have long been practiced. There seem to be several causes responsible for the recent development of large scale stream and lake improvement work on public waters. Most apparent of these is the increasing demand for better fishing, the growing recognition that suitable habitat conditions are essential, and the large supply of available labor. The establishment of the Civilian Conservation Corps has provided a means for management of forests and wild life on a somewhat more intensive scale than hitherto possible. The improvement of angling conditions is a recognized activity of the C.C.C. and a large amount of environmental modification on public waters is being done by various camps situated in areas which afford projects of this type.

In New York State, under the direction of the Conservation Department, C.C.C. camps have included in their projects the enlargement of fish hatcheries, building of lakes, improvement of existing lakes by raising of water levels, and various types of stream development.

Considered upon value per unit area of water, trout fishing ranks above other types of angling. Even a relatively small stream may represent a valuable asset. For this reason, and because the state-owned stream areas are predominantly trout waters, more attention has been directed toward trout stream improvement than toward other problems of fish environmental control. This does not mean that other species cannot be dealt with in like manner! Trout waters are, however, obviously the best starting point, toward a more

intensive system of management. While stream improvement may be classed as a step in the intensive direction, present conditions do not justify work which is very elaborate and costly or involves much upkeep. The aim is to raise the carrying capacities of as large an area of public water as possible at as slight a cost as possible.

The first stream improvement for angling purposes done by the C.C.C. organization in the State consisted of short stretches of experimental work on three Adirondack streams in September, 1933. The next year, this type of work was made a recognized part of the program for camps under direction of the division of Lands and Forests, and Fish and Game, whenever labor is available and the location of camps permits the reaching of streams on state-owned lands. The streams are situated in the Adirondack and Catskill parks, and also in a number of game refuges and reforestation tracts scattered over a large area of the state.

The planning and direction of stream and lake improvements is an activity of the Conservation Department. Field investigations are carried out by the Divisions of Fish and Game, and Lands and Forests. The comprehensive watershed surveys carried on by the Bureau of Biological Survey afford much information of use in planning improvements. Examination of streams, drawing up of work plans, instruction of camp superintendents and crew foremen, and inspection during the progress of the work are necessary steps. The C.C.C. organization at present has two men engaged in direction of the fishing improvements. Mr. Emerson James has acted as construction expert since the start of the 1934 season. During 1935, following extension of the work to approximately twenty camps, Mr. D. B. Cook was assigned to assist in a similar capacity. Numerous camp superintendents and crew foremen have become interested and experienced in stream and lake improvement work.

Effective work is dependent upon accomplishment of whatever is needed for each particular stream. This necessitates individual treatment and blanket instructions for stream improvement are not adaptable to the various conditions encountered. Much of the work is so new, that means for meeting the requirements of individual cases have had to be devised.

During the 1934 field season, 46 miles of trout streams were improved to what we consider the practicable limit. The most important aspect of this work was improvement of pools in shallow streams which need greater depth and more sheltered places suitable to harbor fish of or above the legal size of six inches. Over 2,000 individual pool improvements were installed. These consisted of log and stone dams, retaining walls, readjustment of boulders, deepening, and use of log and stone deflectors to narrow the eroding channel.

The construction used comprised two main types depending upon the nature of stream bottom. Most of the streams have either rough

slab or boulder bottom, too firm to allow driving of stakes. The most successful type of work under these conditions was found to be stone, with log cribbling. Comparatively few streams afforded conditions suitable for use of logs held in place by stakes, an economical method where conditions permit.

Deflectors and dams were used. Angle braces on the upstream sides of the cribbing of dams was found to be essential in many situations in order to deflect the current away from banks. Board facing of dams was found to be far more desirable than use of wire or brush. Scrap lumber was usually available for facing dams.

While a number of different structures have been used, we are narrowing down more and more to two types of dams, several types of deflectors, and one type of retaining wall. Dock spikes, nails, and No. 9 galvanized wire are the principal materials involved. The timber used, mostly dead and down or cull timber, represents a number of kinds. Where constantly submerged, practically any wood lasts very well. For top logs and other use which subjects logs to some drying, the more resistant types of available timber are desirable.

A number of structures have been tried and found lacking in some essentials. Attempts to face a few dams with stone slabs, or sod have been discarded following damage by the water washing under. Examination from time to time for durability has indicated that comparatively few constructions have been materially damaged in the period of about one year. The unparalleled flood of July 8 struck two of the improved streams with force that ripped out a dam and several bridges, as well as many trees and alder clumps. It would not have been surprising if all constructions were found missing but careful check showed relatively slight damage. Those which were damaged, less than 25 per cent in all, were probably washed out through lodging of large amounts of trees, bridge timbers and other flood debris which would not ordinarily be a factor of importance. Check of other work, not in the zone of maximum flood but subjected to rather unusual high water, showed no entire wash outs and practically no other damage except where board facing was not used, in less than ten per cent of the total constructions. The side cribbings on these dams seems likely to last well and the scour hole under the middle of the log makes a very acceptable hiding place for trout, so even these constructions may prove effective. The dams faced with boards are, however, much more desirable and have caused excellent scour pools to develop below them. They do not leak, even in low water, and seem likely to last for many years. All are built low, to stand over-topping by high water.

Planting of willows is one of the most worth-while projects to undertake, particularly on the central New York streams running through abandoned farm land. Deforestation, followed by years of grazing, has destroyed the stream-side shade and allowed the banks

to erode and cause a wide, shallow stream. While these streams can be narrowed by channeling and by use of deflectors, the most economical method of narrowing them is by encouraging brush to grow on banks. Experimental plantings of willow cuttings, made during the spring of 1935 were very successful. The planting of willows is speedy and economical, although the full benefits require several years to develop.

Quite a number of New York trout streams, particularly in the Adirondacks, are damaged by perch, pickerel, bass and other fish. Where such fish invade the streams from below, a very worth-while improvement consists in installation of barrier dams. Several of these have been installed in Adirondack trout streams. Even where bank conditions do not permit building of a dam over a foot or so in height, construction of a wide log apron below the dam, sufficiently long so as to prevent fish jumping across it accomplishes the desired effect. This structure keeps fish from coming close against the dam and the additional horizontal distance between the lower end of the apron and the face of the dam is sufficient to prevent jumping.

A very effective means for improvement is the ditching of lateral springs. Many of these are no more than wet spots before ditching, and expose the spring water to serious warming. After ditching, they flow a narrow, cold spring stream which is a decided asset to the temperature conditions if the stream is dangerously warm, as is often the case. Moreover, the larger springs are often ditched out to a gravel bottom on which spawning can take place. Young trout have been seen in many of the ditched springs in areas formerly closed to them. It should be mentioned that by no means all spring areas are worth the labor of cleaning them out since many of the lateral springs are submerged by the streams during high water and will soon become choked with silt so that ditching in such cases does not produce a lasting result.

Occasionally, a large slide of clay, gravel, or sandy soil contributes tons of debris to a stream. This material usually continues to slide in every year because the stream keeps removing the base of the slope which would otherwise form. By deflecting the current away from such banks and strengthening the base of the slope with log and stone retaining walls, such sliding banks have not usually been difficult to keep in a state of repose. It is expected that some planting of banks may be desirable a few years after the first repair work is done, unless natural vegetation takes possession. Minor eroding points, slight cutting of banks at various points, are less spectacular than the large slides but are probably more important, in the aggregate. Numerous small retaining walls of stone or log and stone have been put in and deflectors have been used to keep the eroding force of the current away from danger points. A number of valuable streamside trees have been protected against undermining through the use of deflectors. A large number of erosion hazards

have been removed, particularly down timber which has become lodged in such a way as to deflect high water against stream banks.

One of the most satisfactory improvements yet undertaken is the concentration of the flow of water through the blocking of side channels. Very frequently this results in the making of a satisfactory stretch of angling water out of a number of shallow, spread-out side-channels which not only were too shallow for the best utilization by fish but were also hazardous in exposing the water to warming.

It is much easier to report on what is being done on stream improvement projects than to state what the results are. Any field of work as new and as full of possibilities as this one, certainly demands careful evaluation of results as a guide to subsequent planning. Effects could be studied by investigation of the recreational value of a stream before and after improvement over a sufficient period of years to allow striking of accurate averages for the periods before and after the work. This sounds well in theory, but involves an amount of time and investigational labor that, at present, rules out this method. Perhaps experimental areas can be set aside, with adequate facilities and personnel for making such thorough studies. Meanwhile, owners of private waters could make important contribution to the available information of stream improvement if they would keep records of catches for some period of years before and after environmental modifications are made. In ecological problems such as this, different answers would be expected with each different complex of environmental conditions and even a very carefully planned test would yield conclusions applicable only to the particular conditions under which carried out.

This difficulty should not lead us to abandon all attempts to check stream improvement but means that we are likely to have to be content with an approximate evaluation rather than a carefully measured result. General evaluation of conditions of streams upon which work was done last year leads to the conclusion that there has been a marked improvement. Fish were caught in some sections of stream which were not, before improvement, suitable for inhabitation by trout of legal size. The recreational value of many streams was increased and there was abundant evidence that many persons enjoyed angling in the improved areas.

Field investigations by the Biological Survey have indicated that there are many streams which are well supplied with small trout but have comparatively few large fish. Frequently, such streams will have a few good pools, each inhabited by one or more good-sized fish. Such pools may be taken as models for the construction of additional pools, which, if not spaced too closely, can each be expected to produce its quota of fish. This is what probably does take place, according to data gathered from field observations.

How much investigational work is required for planning of stream improvement is a question open to some controversy. Much

of the work is relatively simple. For example, some of the wide, shallow, flat streams are so obviously in need of pool improvement that it is not difficult to plan out an effective program for installation of deflectors or small dams. Under other conditions, effective planning demands a large amount of detailed information and the scarcity of exact data regarding the habits and management of the fish life present in the stream is often a serious handicap. This is particularly true since the plans for any one stream should be fitted in to a management plan for the entire system of angling waters. Studies of growth-rate, food, migration, spawning habits, predatory and competitive relationships and the like, are useful and if more detailed knowledge of fish life under natural conditions were available it could be used to advantage. Sometimes two streams of similar conditions should be handled entirely differently, to the best interests of the fish resources concerned. One of them, if tributary to a perch or pickerel lake might best be handled by installation of a barrier dam near the mouth, and by pool improvements designed to encourage the larger size of trout. The other, if tributary to an important trout lake, might best be handled by removal of any existing barriers, improvement of gravel areas in the spring regions for spawning purposes, and maintenance of shallow water to discourage large fish and to permit a maximum development of small fish to supply the lake. Many other examples of the specialized nature of the planning involved could be given.

The ideal situation for carrying out a complete program for the development of the full possibilities of a stream is, of course, when the entire unit of angling water can be managed as a whole. There are limitations, at present, in that publicly-controlled areas, on many streams, are relatively a small percentage of the entire stream course. Much remains to be done, however, before even the more urgent need improvements can be made on the entire mileage of state-owned waters of New York.

Stream and lake improvements constitute only parts of the major problems of how best to manage and develop fish resources. In order to proceed intelligently with improvement, it is necessary to determine what is wrong with the waters concerned and how to correct these unfavorable conditions. This information is also basic to constructive management outside of the limits of stream and lake improvement, especially along the line of prevention of damage through needless cutting of stream-side brush, introduction of fish detrimental to trout, and other destructive practices. As experience is gained in working out the conditions responsible for fish production in sufficient detail to permit application of improvement, it is expected that this information will aid in other ways leading toward a more efficient management of fishery resources.

IOWA STREAM IMPROVEMENT WORK

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Iowa streams of appreciable mileage suitable for trout are not plentiful. For this reason an attempt has been made the past two years with the help of government agencies to improve such streams by installing devices similar to those used in Michigan and other states interested in this type of fisheries work. At the end of two years a survey of the Iowa streams so improved reveal construction faults, ineffectual devices, misapplied principles, and emphasizes a need for combined engineering and biological application.

To demonstrate this fact and to illustrate possibilities of stream improvement, Coldwater Creek, in Winneshiek County, is cited. The creek originates from a spring with a maximum temperature of 50° F. See Figure 1.

Where creek leaves wooded banks and enters pasture area, one-quarter of a mile below spring head, water stays at 53° F. maximum and after stream has meandered three-fourths of a mile through a timberless stretch, one mile below source, the water temperature increases some 12° F. when atmosphere is 62° F. to corresponding raises throughout the summer.

The solution to such a condition is shown in Figure 2.

Where stream bed and banks have a major portion of earthen material and where limestone ledges are only occasional, tree planting and erosional control of banks are fundamental and basic. The trees hinder and will eventually practically eliminate bank erosion, shade will be produced, herbal vegetation will have an opportunity to gain a foot hold on the arrested slopes, cover will be provided, food organisms will increase and maintain a more satisfactory balance with the fish, and water temperature will be kept more stable. The added cover and bank rootlets and projections will permit the trout and other creek denizens to withstand sudden freshets to which northeast Iowa is so frequently subjected.

On state owned lands such a definite program can be pursued. However, practically all of Iowa's trout streams are privately owned and for this reason the cooperation of the land owner must be of longer duration than just during improvement construction periods; the agreements must be of a permanent nature.

In trout streams with eroding banks, cover devices of the raft type were installed as noted in Figure 3.

Due to quantities of silt carried periodically by the streams and due to hydraulic characters, that are known as stream vagaries to the layman, the cover devices were almost one hundred per cent failures, silting up, and deflecting the current against unprotected banks.

Figure 1.—Cold Creek originates from a spring with a maximum temperature of 50° F.

Figure 2.—Temperature rises as Cold Creek meanders through treeless meadow.

Figure 3.—Cover devices of the raft type are used in streams with eroding banks.

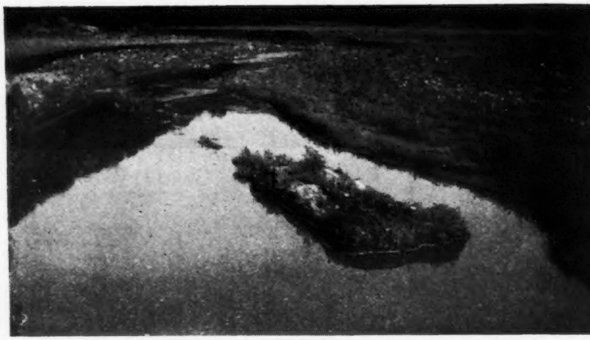

Figure 4.—Covers filled up with silt, forming islands and materially changing the character of the stream.

Figure 5.—Rip-rapping with brush, etc., was found more effective than more elaborate structures.

Figure 6.—Log and rock crib deflectors are effective when located properly.

Figure 4 shows the manner in which covers filled up with silt, forming islands and materially changing the character of the stream.

Where little silt is carried and stream bed and banks are of rock these devices are practical. Better success resulted from the deflectors installed. Here again swift currents between clay banks are hard to control. Rip-rapping with brush, rock, and small trees serve the purpose and many times are more effective than elaborate structures built of logs, brush, and rock. Figure 5 illustrates effectiveness of these deflectors.

Bank deflectors of this type made of salvaged material are recommended because they serve the purpose of deflectors and because they are more economical to install. A small crew of workers can produce a maximum amount of permanent stream improvement by using this method.

The log and rock crib deflectors are effective if located in streams where current will be forced against ledge rocks or boulder-strewn banks. Figure 6 illustrates one of these devices.

This device forces current against banks that will not erode and slide into the stream. This type deflector was also successful when opposite banks heavily rip-rapped with trees, brush and rubble. A careful survey of the stream improvement devices installed reveals the fact that stream hydraulics are of major importance along with biological importance and for this reason we find it necessary and expedient to send an engineer with the stream improvement man to assist in correctly locating the places for installation. In this way, we have an opportunity to make improvements of a more lasting nature. Since this system has been used more satisfactory results are obtained.

The work done in Iowa demonstrates the need first of reforestation and erosional control on the water shed of the streams. As this work is initiated, bank protection by plantings and by mechanical means can proceed, and lastly, actual installation of stream improvement devices are made. The establishment of natural conditions must be the goal in Iowa stream improvement work before attempting to reach this end by purely mechanical means.

Experience shows that we cannot begin in the middle of a problem and go forward with success, but teaches us that we must take into consideration basic fundamental facts and start at that point. I have reference to the mere installation of devices in streams to improve them. Biological factors alone will not improve that stream; a knowledge of hydraulics must be considered just as important as the biological factor. In our later stream work, as we are now doing, we find trained engineers going on the ground and making surveys with the fisheries' men so that there will be no mistake in placing these devices or doing things to the stream that will result in harm.

THE EFFECT OF CRUDE OIL ON FRESH-WATER FISH

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That crude oil and lubricating oils exert a harmful effect upon fish life, when these substances are dumped into our streams and lakes has long been recognized. The deleterious effect of these substances upon fish and other aquatic organisms has quite generally been attributed to the facts, (1) that the oil gathered on the surface of the water prevented the exchange of gases between the water and the atmosphere and thus caused an oxygen deficiency in the water which resulted in the suffocation of the fish, and (2) that the oil formed a film over the gill filaments of fish and of other aquatic animals and prevented the exchange of gases (0_2 and $c0_2$) between the blood of the fish or other aquatic organism and the surrounding water. This again would result in death by suffocation. According to this conception the crude oil and lubricating oils were acting in a purely mechanical manner and their presence in and over the water need not necessarily prove fatal, provided the fish did not come in direct contact with the oil, and as long as there was sufficient oxygen in the water to sustain life.

That crude oil acts in this manner is undoubtedly true and certain experiments performed by the author confirm this view (See Expt's 1-3). However, the writer has also been able to show that crude oil contains a water-soluble fraction which is very toxic to fish life, and this in the absence of a film of crude oil and in the presence of an abundant supply of dissolved oxygen. To obtain these toxic substances from the crude oil, it is not necessary to mix the latter and the water by shaking; it is sufficient to permit a layer of crude oil to stand on the surface of the water for a sufficient length of time. The experiments described below also show that these toxic substances are of a gaseous nature since their effect can be removed by mechanical aeration. The toxic effect of crude oil on fish has been discussed by Gutsell (1). In order that other interested workers may check the writer's results, a number of experiments are given in detail.

The following terms are used frequently in this paper: Initial oxygen has reference to the concentration of dissolved oxygen at the beginning of an experiment; lethal oxygen refers to the concentration of dissolved oxygen when a fish died or lost equilibrium; St. W. refers to the standard water used in all experiments and controls except as modified and as indicated in each experiment. This standard water was prepared by adding sufficient tap water to ordinary distilled water to raise the pH of the latter to 7.7 or 7.8.

The Mechanical Action of Crude Oil

Experiment No. 1. With an 0.2 centimetre layer of crude oil over the surface of the water, fish died in the following order: A five centimetre bream, after one hour, two-six centimetre bass and one-six centimetre catfish after three hours, and one-six centimetre catfish in four hours. When the last fish died, the dissolved oxygen was down to 0.35 p.p.m., showing that the death of at least some of these fish was due to lack of oxygen alone. In the control aquarium stocked with the same number of fish of the same size and species, the dissolved oxygen still amounted to 1.4 p.p.m. and the fish all survived the experimental period. The low dissolved oxygen in the experimental aquarium shows that even a very thin layer of oil interferes with the gaseous exchange between the water and the atmosphere. Neither the control nor the experimental aquarium was areated.

Experiment No. 2. The same number and species of fish were placed in each of two aquaria. The surface of the water in one was covered with crude oil to a depth of 1.5 centimetre. Both aquaria were well areated with compressed air. In the experimental aquarium this resulted in the formation of oil globules which decended into the water to a depth of several centimetres. During the twenty-two hours that this experiment lasted nine bream ranging in length from three centimetre to five centimetre (ave. lgt. 4 cm.) and one-eight centimetre bass (only one bass used) had died in the experimental aquarium while none had died in the control. Three bream ranging in size from three-five centimetre survived the experimental period under the layer of crude oil. These fish died, not because of low oxygen, because the water was well aerated. Nor did they die from the effect of the toxic substance present in the crude oil, for as subsequent experiments (see below) have shown, aeration would eliminate these substances if they had diffused into the water. These fish were probably killed as mentioned under the number two in the introduction (see page one). These fish came in direct contact either by colliding with the oil globules produced by aeration or by swimming into the layer of oil on the surface. That this explanation is valid is suggested by the results obtained in experiment No. 3.

The above experiment was repeated using five bass and nine bream. The bass ranged in size from seven to nine centimetre. Four of these fish lost their equilibrium after nine hours, and in less than thirty hours all had died. The bream ranging in size from three and a half to five centimetre were all dead within seventy hours. The controls were all in good condition and were used for controls in Experiment No. 3. The death of the experimental fish was again due to coming in direct contact with the oil.

Experiment No. 3. This experiment was conducted in the same manner as number two, with the exception that a fine screen was

placed several centimetres below the layer of crude oil; this screen kept the fish from swimming into the crude oil and also prevented the oil globules from striking the fish. Any direct contact between the fish and the oil was thus made impossible. Ten bream (3.5-5.0 cm.) and four bass (6.5-7.0 cm.) were kept under these conditions for seven days without the loss of a single fish. These fish were kept under observation for two weeks after their removal from the experimental tank and no losses occured. This is additional proof that the fish in experiments one and two were injured by coming in direct contact with oil.

The Toxic Effect of the Water-Soluble Fraction

The experiments that follow are designed to show that crude oil contains a water soluble fraction and that this water soluble fraction is toxic to fish. These experiments also suggest that this water soluble fraction is of a gaseous nature since agitation with compressed air removes the toxicity of the mixture.

The medium used in experiments four to seven was prepared by mixing 95% St. W. and 5% crude oil as follows: The water and the crude oil were placed in a glass flask and mixed ten times by shaking (by hand) during the first twenty-four hours. The mixture was then permitted to stand for three days when the clear liquid was syphoned from under the layer of oil. The water, as prepared above, showed no signs of opalescence showing that no oil droplets were mixed with the water; it had a pH of 7.7, dissolved oxygen 2.4 p.p.m. at a temperature of 72° F.

Experiment No. 4. An eleven centimetre bass ceased breathing in this medium in seven minutes. The concentration of dissolved oxygen and the reaction remained unchanged. A control bass of the same size in St. W. maintained its equilibrium until the dissolved oxygen was down to 0.5 p.p.m.

Experiment No. 5. The same medium as in No. 4, except that sufficient oxygen was passed into the medium to raise the oxygen to 5.82 p.p.m. Under these conditions a ten centimetre bass lost equilibrium in three minutes and ceased to breathe in eight minutes. Again the lethal concentration of oxygen was practically the same as the initial oxygen.

Experiment No. 6. Conditions as in No. 4, except that the experimental medium was aerated vigorously with compressed air before the fish were put in. This raised the initial oxygen to 8.0 p.p.m. Two bass (8.5 and 9 cm.) were kept in the experimental container until their respiratory movements were barely perceptible. The dissolved oxygen at that time was down to 0.6 p.p.m.; the same as in the central jar. The loss of equilibrium in this case was caused by lack of oxygen. There was a marked difference in the lethal oxygen in No. 6, on the one hand and in Nos. 4 and 5 on the other.

Before the bass in No. 6 ceased breathing compressed oxygen was

passed into the container and both bass revived. This is additional proof that the loss of equilibrium was due to an oxygen deficiency and not to the presence of toxic substances.

Experiment No. 7. This experiment shows that fish lose their equilibrium in this experimental water even when this water is supersaturated with oxygen. The same medium used in Nos. 4-6 was employed but before the bass were put in oxygen was bubbled (slowly) through the experimental water until the concentration reached at least 14.4 p.p.m. or approximately 163% saturation. Under these conditions a nine centimetre bass lost its equilibrium in 10 minutes when the dissolved oxygen still amounted to 14.4 p.p.m. Five minutes after the bass had lost its equilibrium and had remained on its back compressed air was turned on. In five minutes the bass was again swimming around normally. The air was cut off after an additional twelve minutes had elapsed. The bass was left in the container without further aeration until it again lost its balance. At this time the dissolved oxygen was down to 0.5 p.p.m. A control bass in St. W. lost equilibrium at the same concentration of oxygen.

This experiment shows that the toxic effect of the water soluble fraction of crude oil cannot be counteracted by fairly high concentrations of dissolved oxygen in the medium, but that it may be eliminated by vigorous mechanical aeration.

The next experiment is designed to show that the toxic substances present in crude oil will diffuse into the water when a layer of crude oil is superimposed on the water. A glass bottle was filled with 95% St. W. and 5% crude and left standing unstoppered for four days. Since the water and the oil were never mixed by shaking any toxic substances that were absorbed by the water had to get there by diffusion. The clear liquid was drawn off and used in experiment No. 8. This water had an initial oxygen of 4.9 p.p.m. pH 7.8 at a temperature of 75° F.

Experiment No. 8. Two bass (6 and 7 cm.), five bream (5 cm.), one crappie (5 cm.) and one green sunfish (5 cm.), lost their equilibrium in twenty-five minutes when the lethal oxygen amounted to 2.3 p.p.m. After these fish had all lost equilibrum the water was aerated vigorously with compressed air for twenty minutes. One bream, the crappie and the green sunfish recovered. These fish were left in the jar without further aeration until they again lost equilibrium. However, this time six hours elapsed before they lost their balance and the lethal oxygen was only 0.52 p.p.m.

This experiment was repeated using the same medium but aerating it vigorously for twenty minutes before the fish were introduced. Two bass (6 and 7 cm.) and three bream (5 cm.) lived in this water until the oxygen was down to 0.53 p.p.m. Control fish kept in St. W. lost their balance at the same concentration of oxygen.

Experiment No. 9. In this experiment a mixture of 77% St. W. and 23% crude oil was prepared and left standing for twenty-four

hours before drawing off the clear liquid to be used in the experiment. The oil and water were mixed six times by shaking. In this medium, bass and bream lost their equilibrium in five minutes when the dissolved oxygen still amounted to 8.2 p.p.m. at a temperature of 72° F. These fish were dead in 25 minutes. This experiment was repeated but the water was aerated vigorously for ten minutes with compressed air before introducing the fish. Two bass (8 cm.) and two bream, (5 cm.), lost their equilibrium in 8.5 and 12 minutes respectively. Lethal oxygen 6.4 p.p.m. A second repetition of this experiment in which the water was aerated vigorously with compressed air during the entire period of the experiment, two bass (8 cm.) and two bream (5 cm.) lost their equilibrium in twenty-three minutes and were dead in thirty minutes.

In a similar experiment using the clear liquid from a mixture of 33% crude oil and 67% St. W. that had been standing for 3.5 days, bream and catfish failed to survive, although the water was aerated from the start. This experiment (9) shows that with these higher percentages of crude oil used the effects of the water soluble fraction are rather drastic and cannot easily be offset by mechanical aeration. However, the next experiment shows that if the aeration periods in No. 9, had been more prolonged, the results might have been different.

The following experiment shows that the water-soluble fraction of crude oil may be removed from the water by mechanical aeration even if higher concentrations of crude are used in the preparation of the experimental medium.

Experiment No. 10. A mixture of 25% crude oil and 75% St. W. was left standing tightly stoppered but without shaking for 46 days before the clear liquid was syphoned off. Bass (9 and 10 cm.) lost equilibrium in three minutes when the dissolved oxygen equalled 2.3 p.p.m. When the oxygen was raised to 4.3 p.p.m. by bubbling oxygen through the water, bass of the same size lost equilibrium in five minutes. Some of the gaseous substance that came from the crude oil was undoubtedly removed while the oxygen was passing through the water. This experiment was again repeated but before the fish were placed in the water the latter was aerated vigorously for 45 minutes. Now two bass (9 and 10 cm.) retained their equilibrium until the O_2 was down to 0.49 p.p.m.

The experiments that follow immediately demonstrate the lethal effect of low concentration of crude oil mixed with water. Mixtures of St. W. and crude oil containing one per cent and one-half of one per cent respectively were prepared and left standing for thirty hours. The oil and water were mixed once by shaking when they were prepared.

Experiment No. 11. Using the clear liquid from the mixture containing one per cent crude, the liquid had a pH 7.7, oxygen 7.6 p.p.m. and temperature of 70° F. In this water an eleven centime-

tre bass lost equilibrium permanently in 24 minutes and a six centimetre bream in fifteen minutes. Lethal oxygen 5.9 p.p.m.

This experiment was repeated after the same water used in the first trial had been aerated vigorously for fifteen minutes. Two bass (9 and 11 cm.) in the same volume of water as was used in part one of this experiment lost their equilibrium after two hours and thirty-six minutes when the dissolved oxygen was down to 0.49 p.p.m. (the initial O_2 was 7.9 p.p.m.). These fish recovered when transferred to tap water after loss of equilibrium.

Experiment No. 12. Using the clear liquid from the mixture of oil and water containing one half per cent crude, this water had an initial oxygen of 7.6 p.p.m. at 70° F. In this water an eleven centimetre bass lost equilibrium in 32 minutes and a six centimetre bream in 23 minutes, when the oxygen had been reduced from 7.6 p.p.m. to 3.3 p.p.m. This shows that while this water was still toxic it was not as toxic as when one per cent or more of crude oil was mixed with the water.

The Effect of Refining Upon the Toxicity of Crude Oil

The next experiment shows the effect of refining upon the toxicity of crude oil. In this experiment the clear liquid from a mixture of ten per cent Sinclair Pennsylvania Motor Oil and ninety per cent St. W. was used. The water had been in contact with the oil for thirty hours and the mixture had been shaken vigorously five times. The liquid from the mixture of oil and water contained 7.5 p.p.m. of oxygen at a temperature of 70° F. The pH was 7.7. Two bass (9 and 11 cm.) lost their equilibrium in three hours when the dissolved oxygen had been reduced from 7.5 p.p.m. to 0.5 p.p.m. This experiment seems to show that refining removes the greater part of the water-soluble fraction of the crude oil and renders the refined products far less toxic than the original crude. The extent to which lubricating oils are rendered non-toxic undoubtedly depends on the degree to which they are refined. The cheaper grades of lubricating oil would probably be less completely detoxified.

Conclusion

In the above experiments two criteria have been used to determine the effect of the crude oil and of the water-soluble fraction extracted from the crude oil upon the fish, namely, the length of time that fish survived under experimental conditions as compared with controls, and the amount of oxygen left when the fish lost equilibrium or died. Of these two criteria the author considers the last one mentioned of greater significance than the first. The survival time depends not only on the effect of the experimental substance upon the fish, but upon the mass of the individual and the total mass of fish used in a given quantity of water as well. Hence, to measure the effect by length of survival time only might lead to erroneous

conclusions, for if the lethal oxygen is not determined, it is impossible to state whether the fish were injured by the substance under investigations or simply by suffocation. Moreover, from a very extensive series of experiments (2) and other unpublished data it has been shown that within the normal range of pH and temperature bass and several other species of fresh water fish can reduce the dissolved oxygen in the water to well below one part per million. So, in the above experiments when a fish died or lost equilibrium when the dissolved oxygen amounted to more than two parts per million, in one instance to 14.4 p.p.m., it has been assumed that the fish lost equilibrium or died from the effects of a toxic substance, in this case the water-soluble fraction of crude oil. Moreover, these lethal concentrations of oxygen were always checked against the lethal oxygen in the controls and that of the experiment where the experimental water was prearrested. It may be repeated that in some of the experiments where the survival time was only a few minutes, there was practically no diminution in the dissolved oxygen during the experimental period. It might be pointed out too that in some of the experiments the initial oxygen was much higher than in others. This, however, has no significance as far as the lethal oxygen is concerned. In the paper already referred to it has been shown that under normal conditions the initial oxygen has no effect upon the lethal oxygen. The pH and temperature in all these experiments have been maintained at such levels that no injury to the fish could be ascribed to variations in these factors.

Summary

(1) The effect of crude oil upon several species of fish has been investigated.

(2) This investigation confirms the mechanical action of crude oil as stated in the introduction.

(3) It has also been shown that crude oil contains a water-soluble fraction which is very toxic to fish.

(4) The toxic properties of the water-soluble fraction of crude oil can be eliminated under experimental conditions by mechanical aeration.

(5) It follows from these experiments that the promiscuous discharge of crude oil and other waste oils into our natural bodies of water is detrimental to fish life and should be prohibited.

Literature Cited

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Discussion

Mr. Aitken: Did you try any of these experiments in any outdoor condition on a small scale?

DR. WIEBE: No.

DR. HUBBS: In connection with an experiment we have been carrying on at Ann Arbor, will you say that any oil pollution can be corrected by aeration in an aquarium?

DR. WIEBE: No, I would not say that.

DR. HUBBS: Possibly you could enlighten us in regard to our own case. We have been interested in a bay in the Lake Erie area where the oil pollution is of long standing, the oil having for the most part accumulated on the bottom, forming a sludge which occasionally boils up producing a scum at the surface—at least so we think. Mr. Rodeheffer has been doing field work in that connection. One experiment which he tried was to bring in some of that bottom sludge with some of the vegetation which is growing so luxuriantly in the bay and place that in an aquarium of about forty-five gallons with three air outlets. Fish placed in this aquarium died in about twelve to twenty-four hours.

DR. WIEBE: Was the aquarium pretty fully aerated?

DR. HUBBS: Yes.

DR. WIEBE: Making considerable bubbles?

DR. HUBBS: Yes.

DR. WIEBE: Then there must be something else.

DR. HUBBS: This experiment I refer to is one indication of the long standing effect that may come through oil pollution. The effect may last for several years because the sludge continues to boil up material which is deleterious to fish life.

NOTES ON COSTIASIS

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Costia nectarix is the most deadly of the protozoan parasites infesting Speckled Trout. Reproduction takes place at an enormous rate and the infection is quickly fatal to fry and young fingerlings, but beyond the fingerling stage there is little danger of heavy mortality.

When severely infected the fry struggle to maintain their normal position, but as soon as they relax they turn on their backs and float on the surface of the water, weakly bending from side to side and with their pectoral fins moving feebly. When fish are in this condition costiasis should be suspected and specimens carefully examined with hand lens and microscope.

If Costia is present the lens will show notched and frayed fins, particularly the dorsal and caudal, and in severer cases patches of bluish slime appear on the body.

The most satisfactory method of making a microscopic examination is to cut off an infected fin and place it on a slide with the high power objective (4mm.) focused at the apex of a deep notch in the fin. Here will be seen great numbers of minute round dots dancing or oscillating rapidly; not usually moving definitely in any direction. These are the younger forms having a tough outer coat and are difficult to destroy by immersions. Occasionally larger, clear and oval forms move definitely across the field; these are the larger forms and are more easily killed by immersions, as it is almost impossible to find any of them alive after the fish have been dipped in three per cent salt solution for 10 minutes or 1:500 solution of glacial acetic acid for one minute.

It is apparently not the damage done to the fins and body which causes death, but their presence in large numbers on the gills which interferes with respiration.

It should be emphasized that larger fish, advanced fingerlings, yearlings and even adults frequently carry the parasite without apparently being affected. This observation is true also to some extent of most other diseases particularly where protozoans are concerned, and consequently all troughs and raceways where fish are retained should be thoroughly sterilized and preferably painted or tarred inside before any fry are transferred.

It is known that periodic immersions in salt solution (three per cent for 10 minutes) or glacial acetic acid (1:500 for one minute) carried out at intervals of two or three days will kill the parasite, but it is not a simple matter when dealing with the infection on a large scale and there are practical difficulties which are enumerated below.

(1) Healthy fry and one inch fingerlings would in many cases not withstand the immersion for this length of time. Fry already weakened by the disease are even less able and all infected fish might be killed by following this prescription rigidly.

(2) The salting is done in the troughs where the fish are retained that all free-living forms may be killed. The salt must be measured, the level adjusted, the water shut off, the salt scattered in the trough, and stirred with feathers till dissolved, which requires 10 or 15 minutes before the solution reaches 3 per cent. The fry are subjected to an increasing strength of salt and may be injured by stirring. After 10 minutes in three per cent solution the water is turned on and the solution will not be completely changed for some time.

(3) Thus the fry are in "dead" water for half an hour or more and suffer a great reduction of oxygen as well as a strong concentration of salt.

(4) If the troughs are not clean before salting a large mortality will result from small particles (which normally lie on the bottom) becoming suspended in the brine and adhering to the gills of the fish.

(5) There is a tendency to lower the water in the troughs considerably in order to save salt but in view of the reduced oxygen it is better not to lower the water below 4 inches.

(6) During the treatment the sides and top of the troughs must be washed with a strong salt solution.

The alternative would be to dip the fry in a three per cent salt solution, transferring them to sterilized troughs, but in practice the loss is greater due to mechanical injury and the length of time required is prohibitive when working on a large scale. The same is true of the acetic acid treatment.

If serious mortality is to be avoided the infection must be anticipated, treating the fry periodically in a salt solution as strong as they will stand. When it becomes necessary to transfer some to the raceways these should be thoroughly sterilized, painted and left empty for several days. A few fry should then be placed out and observed for several days before transfering a large number.

If such treatments were routine it would incidentally insure against outbreaks of other protozoan parasites, e. g., Cyclochaeta and Chilodon.

COPEPOD INFECTION OF SPECKLED TROUT

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The parasitic copepod *Salmincola edwardsii* is of much concern in speckled trout hatcheries. This parasite has retained the characteristic chitinous cuticle which gives it great protection. It has caused very serious trouble in many hatcheries in the United States and Canada and all attempts to cure the condition once firmly established have been, so far, merely palliative.

This copepod is very widespread in trout waters in North American and Europe. It was first recorded by Linnaeus in 1761 but attracted very little attention till it made its appearance in trout hatcheries. Here it found conditions so ideal for its existence that it came into prominence as one of the major problems in connection with the propagation of speckled trout.*

The free-living nauplii in natural conditions may be eaten by plankton-feeding fish, and after finding a host many of them remain sterile due to the failure of the male and female to come together. In rapid flowing streams the nauplii are quickly swept away and must experience great difficulty in becoming attached. It is the trout in quiet waters that are most susceptible to this form of parasitism. When infection first becomes established there is very little evidence of the disease. The irritation caused by the nauplius causes a small spot of mucus to form in which the parasite becomes imbedded, and in which it soon appears as a thin black line just visible to the naked eye. This is the stage shown in Diagram 2. Spots of mucus, especially on the gills should be examined with a low power microscope. If the disease is detected at this early stage a great deal can be done to prevent its spread by the application of salt treatment and segregation of infected specimens. When the disease reaches an advanced condition the egg sacs of the copepods are often seen projecting beyond the gill covers. In the final stages preceding death the fish are seen with the mouth continuously open except for an occasional snapping of the jaws. Sometimes they shake their heads violently from side to side in a frantic but hopeless effort to get rid of the parasite. Ultimately they lose their sense of tropism and wander about aimlessly until swept against the screen where they soon die. As regards feeding, the infected fish appear ravenously hungry and require more food than usual, which indicates that nutriment is being withdrawn by the parasites. The spawning of the fish is not seriously affected. The yield is not decreased but the eggs are slightly smaller than would be expected under optimum conditions and there is to some extent a lack of vitality among the de-

*Rainbow and brown trout are immune, this copepod being specific on speckled trout.

veloping fry, depending on the degree to which the adults are affected.

The disease cannot be inherited as some people believe; although the nauplii may be brought into the hatchery among the eggs they would die long before the eggs hatched. Many badly infected fish succumb during and following spawn-taking operations. In the more detailed observation of infected fish it is seen that the majority of the parasites are situated on the outer fringe of the gills, although many are also located less superficially. All those visible to the naked eye are females and are provided with two elongated egg sacs, each of which contains seventy to one hundred eggs (Diag. 5). Examination shows that in all cases where the disease is advanced the gills are affected most severely. In addition to this the fins (except the adipose), the inside of the mouth and nostrils, the isthmus and the fringe of the opercle are very susceptible. None have been found directly on the scale-covered parts of the body. A striking fact in this connection is that the adults are by far the most severely parasitized, while yearlings and fingerlings seldom have the disease. Fingerlings about seven months old have been found with one or two parasites. Age is therefore not a preventitive factor but the susceptibility varies directly with age and size. When the gills are badly infected the operculum is prevented from closing and the fish's respiratory movements are seriously hampered. Its consequent decrease in strength and resistance render it an easy prey to further attacks of this and other diseases. The actual pain caused, the withdrawal of nutriment and the distortion of the tissues at the point of attachment are serious factors in the effect of this parasite.

The life history of this organism has been described by Fasten in his paper "The Brook Trout Disease in Wisconsin Waters," but the present description is based on the writer's observations which confirm Fasten's work in all essential points. The nauplius can be made out indistinctly in a ripe egg, the eye, the yolk, and the attachment bulb being especially prominent. The appendages are so distorted that it is difficult to make them out distinctly. The bulb is attached to a filament which is coiled between the posterior margin of the bulb and the eye. If the egg is ruptured, this tube can be extended. When fully developed the nauplius ruptures the egg membrane and is free to search for a host. It has two powerful swimming appendages equipped with plumose setae which it uses alternately like a man doing the crawl stroke. This propels it through the water with a jerky twisting movement. The powerful rasping mouth parts are visible under the head. The attachment bulb and tube are ventral but appear clearly through the transparent body. When the nauplius finds the required host and a suitable point of attachment it rasps a hole with its claw-like mouth parts. Into this hole the attachment bulb is inserted. At the same time the swimming appendages are lost and the body loses all appearance of segmenta-

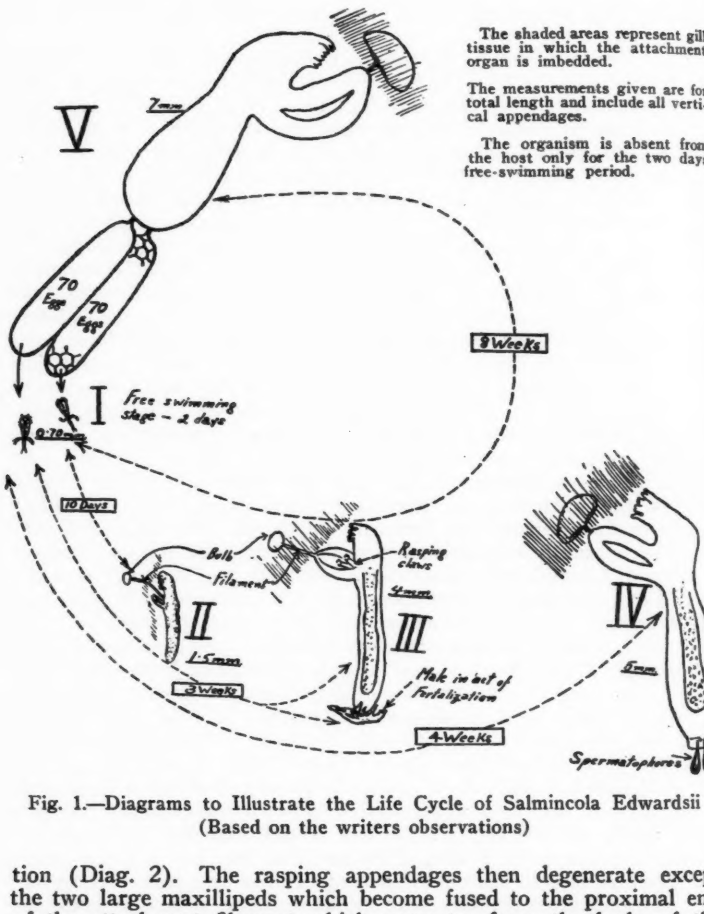

Fig. 1.—Diagrams to Illustrate the Life Cycle of Salmincola Edwardsii (Based on the writers observations)

tion (Diag. 2). The rasping appendages then degenerate except the two large maxillipeds which become fused to the proximal end of the attachment filament which separates from the body of the parasite. We then have a condition shown in Diagram 3. It is at this stage that fertilization takes place, about three weeks after attachment, though there appears to be a fairly wide range during which fertilization can take place. The male is very diminutive (1.2 mm.) and after depositing two spermataphores with tubes leading to the genital pores of the female he drops off and dies. After the egg sacs form the eggs pass into them from the spermataphores.

The body of the female increases enormously and the attachment filament become very much shorter, so that the maxillipeds appear to be attached directly to the bulb. The bulb also expands greatly in the tissue of the host providing secure anchorage (Diag. 4). Fasten gives it as his opinion that the copepod obtains its nourishment from the fish through the attachment bulb and the arms of maxillipeds. This however seems unlikely to the present writer, who has observed the organism manipulating the tissues of its host with its mouth parts and swallowing small fragments of tissue and blood. It appears that the bulb merely serves as an organ of attachment. The time required to complete the life cycle is approximately eight to ten weeks, and seems to depend on the time at which fertilization takes place. The free-swimming nauplius shown in Diagram 3 measured 0.70 mm., and when in motion could be detected by the naked eye. After attachment the nauplius grows very rapidly and in about four weeks it is about six to eight times its original size and has undergone all the essential changes from the active free-swimming to the degenerate parasitic stage. During the subsequent four weeks it merely increases in size and develops its numerous progeny. The sizes and ages shown on the accompanying diagrams are approximate and there is evidence of considerable variation in the rate of growth and development, depending on the place of attachment and the time of fertilization; for instance those which become attached to the gill develop more rapidly than those attached to the fins or mouth. The females produce two batches of young and then die, but remain attached to the host till they disintegrate.

The mechanical removal of the parasites has so far proved the most practical method of combating the disease after it has become established. This requires two operators, one to hold the fish and one to remove the parasites with forceps. With practice this can be done very rapidly and the fish show remarkable recovery. After this treatment the fish are placed in a six per cent solution of Sodium Chloride, which is capable of destroying the nauplii and the early stages after attachment. This salt treatment should then be repeated at intervals of about two days as an extra precaution. The drawback to this method however is the fact that there are usually some forms present, too small to be detected and removed mechanically, and yet far enough advanced that they can resist the salt solution, especially as they are imbedded in mucus which provides further protection. These will later develop to carry on the infection. However, if the fish are kept free from a new source of infection, the few remaining forms may be removed just before they reach maturity (about four weeks after the first batch were removed). Thus the fish may be entirely cured. This method is very successful where a small number of fish are involved. After a treatment the fish when recovered show considerable immunity, and if they become diseased again it is in a milder form and rarely causes the death of the fish.

If the fish are not very severely infected the most practical method of control is to modify the environment so that the fish are retained in fast well aerated water; in this way the disease may be kept at a standstill or even decreased, but not eradicated. There are many expedients which may be adopted to combat the disease, none of which are completely effective. The most satisfactory procedure is to get rid of all sources of infection and gradually replace the diseased fish with a new stock. This may be accomplished by removing all fish from the supply waters and placing all diseased fish in the lowest pond available. The upper ponds should then be left dry for some time before they are used for the new stock. There are many difficulties in carrying out this plan. For instance, in the case of a rearing station which receives its water supply from a river or lake it is impossible to get rid of all sources of infection, and some of the other less satisfactory methods will have to be adopted. Then, there are many hatcheries where it is impossible to dry out the ponds completely—there is usually a stream of water flowing through unless arrangements have been made to divert it. In this case the greatest danger lies in the possibility of one or more infected fish being left in the pond which will spread the disease to the new stock. In cases of this kind freshly slaked lime may be used to good advantage. Sufficient may be placed in the stream to stupefy the fish present so that they are washed down to the screen and easily taken. When this solution of lime reaches the ponds below it is so diluted that it has no ill effect. All underground channels, or other places where fish might be hidden should, where possible, be exposed, or if this is not feasible they should be thoroughly limed as described above. Another precaution which must be taken is to prevent any contact between the diseased fish below and the healthy fish above. It is not sufficient to have a screen separating the two ponds as the nauplii are quite capable of swimming through to the unaffected fish, especially if the current is not very strong. A dam between the two ponds forms the best method of protection as the falls constitutes an impassable barrier for the nauplii. If the ponds are not separated by a dam the outlet should be narrowed till a rapid flow is obtained and then two screens placed, one at the outlet of the upper pond and one at the inlet of the lower pond, thus leaving a neutral space which it is unlikely the nauplii could traverse. Even under normal conditions it is advisable to have some such arrangement at the outlet of the last pond so that no infection can spread upstream from the wild fish below.

The point to be emphasized is prevention. The following points are of paramount importance:—

(1) All fish should be removed from supply water.

(2) Ponds should be free from shallow bays and "dead water" as much as possible.

(3) Fish should be immersed in six per cent salt solution before being placed in ponds.

(4) Under no circumstances should wild fish be placed in hatchery ponds.

(5) Adult fish should be examined frequently so that early stages may be detected.

It will also be evident that it is of great importance in the construction of a rearing station to have a supply of water which can be easily controlled and kept free of fish, and, secondly, that the ponds should be fairly narrow with straight sides and so constructed that they can be operated individually so that each can be completely dried out without interfering with the others.

(Use of 1 per cent urethane as anaesthetic recommended to facilitate handling of affected fish when parasite is removed by hand.—Ed.)

A CHEAP SUPPLY OF WARM WATER FOR WINTER HATCHING AND FEEDING OF SPECKLED TROUT

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The effect of temperature on the growth of trout is well known, and needs no comment here.

During the winters of 1932 and 1933 small quantities of water were heated from approximately 32° to 50° F. In 1932 between two and three imperial gallons per minute were heated by electricity and in 1933 between five and six imperial gallons were heated by the use of oil as fuel. The results, although anticipated, were gratifying as far as the growth of the fish and the loss were concerned. In both years feeding commenced about the middle of January. This was excellent but the amount of warm water was insignificant and the cost extremely high. The consumption of oil amounted to a cost of eighty cents a day, and that of electricity at five cents a kilowatt hour to forty cents daily for approximately half the amount of water. On the score of cost there was nothing to choose between electricity and oil, and both were too expensive for large scale operation.

In order to secure a large supply of warm running water throughout the winter, direct heating of the water was out of the question. Instead of heating the water we decided to pump it and permit it to take up heat from the air. That is to say the water would be in continuous use. In order to keep the water relatively clean, a sand filter was installed, designed for 50 per cent efficiency in removing bacteria. The filter was approximately eight feet by fifteen feet with a depth of two and one-half feet. Beneath the filter there is a settling basin, sixteen feet by five feet. This basin receives the water from the fish troughs and has a depth of eighteen feet; sufficient that is to settle any faeces or food that may enter the return flume when the troughs are being cleaned. The filter is graded from very fine sand at the top to pebbles and rocks on the bottom. The water is pumped from the settling basin to the ceiling, a distance of eight and a half feet. It is pumped against a baffle (metal) and falls into a metal hopper, and from there to the top of the filter. From the bottom of the filter it flows immediately to the head trough. The pump is run by a 1½ h.p. electric motor, designed for continuous use. There is an electric alarm attached to the filter which operates whenever the water level in the filter falls to a certain point.

The total quantity of water in the system is 3,300 imperial gallons, which is pumped at a rate varying from thirty to forty gallons of water a minute, the rate varies according to the time between cleanings of the filter. That is, the water is used eighteen times a day,

and in order to keep the temperature *down* to 50° F. during the winter months, it was necessary to admit one thousand gallons (approximate) of water daily, nearly a third of the total water in the system. The cost of pumping this water, paying two cents a kilowatt hour, comes to between $5 and $7 per month. The cost of installation was however quite high, between $1,000 and $1,200.

One hundred thousand eggs from wild speckled trout were placed in ten wooden troughs, fourteen feet long and fourteen inches wide, during the last three weeks of October. The eggs began to hatch towards the end of November and feeding commenced on the 6th of January. At the end of May we had just under 50,000 two and one-half-inch fingerlings. I consider this loss satisfactory though others may not. It compares favorably with my experience in our other hatcheries, and the figures in this instance are accurate. This result was very satisfactory. It means that in the Province of Quebec we can now double the length of our growing season; we now have eight months instead of four.

The Provincial Hygiene Service kindly took bacterial readings for us. They tended to show that the filter in practice was seventy-five per cent efficient in the removal of bacteria, and not fifty per cent as expected. It is to be noted here that the readings were for B coli; it was assumed that if these bacteria were removed, then so were any others present. The filter was designed by Prof. R. E. Jamieson of McGill University. Its size and composition was difficult to determine as a first effort. At the suggestion of Prof. Jamieson ultra violet rays were used to destroy bacteria in the water to reduce the load on the filter. Although this part of the work is still being carried on, it would appear that with the use of ultra violet rays the size of the filter can be reduced to one tenth of its present dimensions. This would mean a reduction in the cost of installation but an increased use of electricity.

The work so briefly described above was done under the direct care of Mr. George Belknap, superintendent at Magog, Quebec. It is hoped that a more complete report will be prepared when the remainder of the work has been finished.

NUTRITIVE VALUE OF THE BLUE CRAB (*CALLINECTES SAPIDUS*), AND SAND CRAB (*PLATYONICHUS OCELLATUS* LATREILLE)*

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This study is concerned with two species of crabs of importance on the Atlantic Coast. They are *Callinectes sapidus,* known as the blue crab and *Platyonichus ocellatus,* Latreille, known as the sand crab.

The blue crab is the most abundant and, next to the lobster, the most important crustacean of our waters. Its range is from Massachusetts Bay to South America and is commonly taken from Cape Cod to Texas. Delaware Bay, Chesapeake Bay and the protected channels along the South Atlantic and Gulf Coasts swarm with blue crabs. Chesapeake Bay is especially favorable and has long been famous not only for the great number, but also for the size of the crabs which it produces. The blue crab is caught and marketed in both soft-shell and hard-shell conditions. For the most part they are eaten fresh. A small but increasing number are canned.

The sand crab, also known as the lady crab, is abundant on nearly all our sandy shores from Cape Cod to Florida, and in the Gulf of Mexico. This species is used as bait on many parts of the coast. It is also an important article of food.

When one considers that in a year, using 1932 as an example, the total catch of crabs for the United States and Alaska amounted to 81,453,000 pounds, worth $1,501,000, it is evident that a large amount of crab meat is consumed and that information concerning its nutritive value is of interest. The object of this study is to determine the biological value of the protein of the blue and sand crabs and to obtain information regarding the chemical composition of the edible portion of these two crabs.

PREVIOUS INVESTIGATIONS

A search of the literature revealed no determinations of the biological value of the protein of either the blue or sand crabs and no analyses for any of the inorganic constituents of the sand crab meat. Hatakoshi (7) found *Chionectes phalangium* Fabr. had the following percentage composition: moisture 77.65, protein 19.35, fat .85, ash 1.95, and carbohydrates .23. Fellers and Parks (5) determined the percentage composition of the Japanese crab, *Paralithodes camtchatica,* to be moisture 77.65, protein 17.54, fat 2.58, ash 1.53, and iodine 362 parts per million; and of the Dungeness crab, *Cancer magister,* moisture 80.98, protein 15.52, fat 1.82, ash 1.69, carbohydrates .2 to .5, and iodine 102 parts per billion. The composition of the blue crab, *Callinectes sapidus,* expressed in percentages by Tressler (20) is moisture 77.07, protein 16.64, fat 1.96, and carbohydrates 3.3. According to Kondo and Iwamae (10), the Japa-

* Contribution No. 223, Massachusetts Agricultural Experiment Station.

nese crab has the following percentage composition: moisture 77.69, protein 19.48, fat .29, ash 1.77, and carbohydrate .74. Lin (11) found *Grapsus nankin* contained .21 per cent fat, 4.88 per cent ash, and .58 per cent phosphorus. Rose and Bodansky (16) found respectively five and .021 parts per million of copper and zinc in the blue crab, while Severy (17) found 2.5 and 31 parts per million, respectively, of copper and zinc in *Callinectes hastatus*. Wells (23) determined the iodine content of the soft blue crab to be 490 parts per billion (dry basis) and of the canned Japanese crab to be 740 parts per billion (moist basis). Wells and Tressler (21) found 180 parts per billion of iodine in the meat of blue crab. Chapman (2) detected 130 parts per million of copper and 17 parts per million of lead in crab meat (species not given). Arsenic, to the extent of 45.6 parts per million is reported in crab meat by Chapman and Linden (3). Newell and McCollum (14) in a spectrographic examination of marine products including crabs found calcium, iron, magnesium, phosphorus, potassium, and sodium in considerable amounts. Traces were found of aluminum, chromium, copper, lead, lithium, manganese, and strontium.

Osborne and Mendel have firmly established the conception that the nutritive value of proteins is largely determined by the amounts of each of the amino acids which they yield. Several investigators, including Kondo and Iwanae (10), Lin (11), and Okuda, Uematsu, Sakata, and Fijikawa (15) determined the cleavage products resulting from the hydrolysis of crab meat protein. All of the essential amino acids are present. In the Japanese crab the percentage composition of the amino acids in the protein is tyrosine 1.87, lysine 5.88, histidine 2.21, arginine 8.75, and tryptophane and cystine, present. *Grapsus nankin* contains typrosine 5.62, tryptophane 1.48, lysine 9.74, cystine 1.74, histidine 2.12, and arginine 7.54 per cent. The proteins of these crabs compare very favorably in composition with those of beef or chicken. The only study reported on the value of crab protein for growth is that by Suzuki, Matsuyama, and Hashimoto (19) on "talapa" crab. When fed at the ten per cent protein level to rats, this crab meat yielded a normal growth curve. At the seven per cent level, the crab meat gave growth comparable to that obtained with beef protein.

The only vitamin study reported is that of Shimoda (18), who fed ether extracts of the meat of several species of crabs at various levels to rats. Good growth was obtained when a five to ten milligram dose was fed. Rats receiving none of the ether extract failed to show any weight gains. This is interpreted to mean that vitamin A is present.

Experimental Part

Samples of freshly picked blue crab meat were obtained as required from Queenstown, Maryland, during the autumn and winter of 1934-1935. This was not salted or brined but was shipped by express and arrived at Amherst in good fresh condition. The meat of the sand crab was secured from a picking house on the Boston waterfront and was

transported in one case to Amherst by automobile. A second sample was supplied by Frosted Foods Corporation of Boston. This sample was solidly frozen when received, and was kept in this condition at 0° F. until dried for analysis or feeding experiments.

All samples were dehydrated in a current of air on large shallow glass pans in an oven at a temperature of 95° to 104° F. to a fine dry powder. This powder was stored in sealed glass bottles after grinding very fine. The product was white and had an agreeable flavor and odor. The powder kept indefinitely in glass-stoppered bottles. There should be important culinary uses for this product.

The methods of analysis of the Association of Official Agricultural Chemists were used except for phosphorus, which was determined by the method of Fiske and Subbarow (6), iron by the McFarlane method (13), copper by a modified carbamate method (12), manganese by the method of Willard and Greathouse (24) and iodine by a modification of the von Fellenberg method (9).

Composition of Crab Meat

Each value given in the proximate analyses represents the average of at least four separate determinations. The mineral analyses are the result of at least two determinations. The results are given in Table 1 and are largely self-explanatory.

The meat from both species of crab is very similar in chemical composition. In fact, all the crabs show great similarity in this respect. On the basis of food value, the meat is little different from animal meats. Crab meat contains a relatively high ash content and the alkalinity of the ash is high due to large amounts of the basic constituents, potassium and calcium. The calorific value is only moderate at 75 to 90 calories per 100 grams. The fat content is relatively low, but it is likely that this constituent shows seasonal change as was found by Fellers and Parks (5) in the case of *Cancer magister*. It is also likely that the inorganic elements in the crab will vary somewhat at the moulting periods.

TABLE 1.—COMPOSITION OF THE EDIBLE MEAT OF THE BLUE CRAB AND SAND CRAB

Determination	Blue Crab		Sand Crab	
	Moist Basis Per Cent	Dry Basis Per Cent	Moist Basis Per Cent	Dry Basis Per Cent
Moisture	79.04	......	76.28	......
Dry matter	20.96	......	23.72	......
Total ash	2.15	10.28	1.77	7.45
Crude Protein (Nx6.25)	17.95	85.62	20.28	85.49
Ether extract (fat)	0.39	1.86	0.24	1.03
Carbohydrate (diff.)	0.47	2.24	1.43	6.03
Alkalinity of ash	11.65	55.60	12.87	54.30
Cal. per 100 grams (Sherman)	77.2	......	89.8	......
K	0.188	0.897	0.153	0.734
Ca	0.133	0.635	0.134	0.639
Mg	0.012	0.057	0.008	0.039
P	0.038	0.182	0.047	0.199
Fe	0.0020	0.0094	0.0015	0.0071
Cu	0.0013	0.0061	0.0012	0.0055
I (p.p.b.)	322	1,585	464	2,215
Mn	trace		trace	

The meat of both species tastes sweet when freshly picked, but soon loses this desirable characteristic. If very fresh crab meat could be subjected to immediate chemical examination, no doubt a considerable glycogen content could be demonstrated. The iodine, copper, and iron values in the meat from both species are high and their presence distinctly increases the nutritional value of crab meat.

Biological Value of the Crab Meat Protein

The biological value of the crab meat protein was determined by two feeding experiments with young albino rats. Adequate diets were used which were alike in all respects except in the source of protein. The percentage composition of the diet was protein 9, butter oil 3, cod liver oil 2, agar 2, McCollum's salt mixture (4) as modified by Bing, Adams and Bowman (1) 2.9, treated starch 12, untreated starch 65.9, calcium carbonate 1.5, and primary potassium phosphate 1.7. The treated starch was that on which the wheat germ extract was dried and supplied vitamins B and G. The extract was made by treating the wheat germ with 70 per cent alcohol in a closed vessel at 150° F. for 60 minutes. The alcohol extract was recovered by pressing. The alcoholic extraction of the marc was twice repeated and the combined extractions, filtered, concentrated in a vacuum pan at 20 inches of mercury, and dried on an amount of starch equivalent to two per cent more than the weight of the original wheat germ. The treated starch was ground to a powder and incorporated in each ration at a 12 per cent level.

The dried, powdered crab meat was incorporated in the rations at such a level that 9 per cent protein was present. Thus, all the protein present in the ration was crab meat protein. Technical grade casein and also vitamin-free casein purchased from the Casein Manufacturing Company of America, New York City, were used for purposes of comparison with other series of rats.

The ration was fed to each of eight young albino rats for a test period of 35 days. The rats were housed in individual cages and an accurate record kept of the weight of food consumed. All the rats ate the crab meat rations very freely. The casein rations were consumed in somewhat smaller amounts by the rats, and although theoretically adequate from a nutritional standpoint, did little more than maintain weight during the experimental period.

Results of Feeding Trials

The data are graphically presented in Figure 1.

The gain in weight per gram of protein consumed was 2.3 grams for the rats fed the diet containing the meat of the frozen sand crab. The rats on this diet made an average gain of 60.8 grams during the 35 days of the test. For the rats on the diet containing the frozen blue crab meat, the gain in weight per gram of protein consumed was also 2.3 grams. The rats on the latter diet made an average gain of 65.7 grams during the same period. The rats on the canned blue crab diet made an

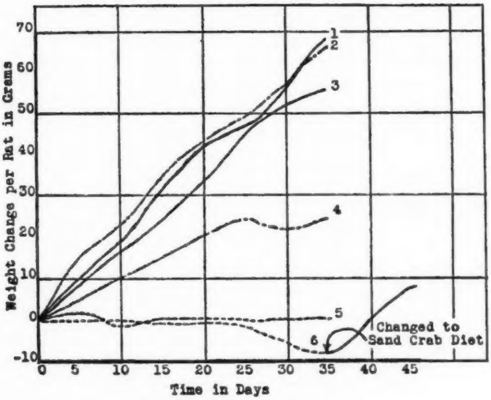

Fig. 1.—Comparison of the Biological Value of the Protein of the Blue and Sand Crabs with that of Casein at a 9 Per Cent Level.

average gain of 25.2 grams during the 35 days' test period. The rats on the control diet containing the technical casein made no appreciable gains in weight. The rats receiving the highly purified casein as a sole source of protein lost weight and died. By the thirty-fifth day of the test the rats on the purified casein had lost on the average of 7.5 grams. At this point they were switched to the sand crab diet and in 10 days the average gain per rat was 16 grams.

The results of the feeding experiments indicate that the two frozen crab meats have about the same nutritive value. The experiments also indicate that the canned blue crab is not as satisfactory as the frozen blue crab meat for rats as a sole source of protein. Apparently the crab meat lost some of its growth promoting value for rats by the treatment to which it was subjected in the process of canning. Under the conditions of this experiment, crab meat protein appears to be definitely superior in quality to casein. However, we can not state with certainty that this assumption is true. Greater total food consumption is probably an important factor in determining the larger weight gains of the rats fed crab meat in place of casein. Total food consumption in grams for the 35-day experimental feeding period was as follows: Diet containing frozen sand crab, lot 1, 293.3; frozen sand crab, lot 2, 304; frozen blue crab 323.1; canned blue crab 253.3; technical casein 173.9; and vitamin-free casein 186. The crab meat improved the palatability of the ration.

Had the rats fed casein eaten as much as the rats fed crab meat, it is problematical whether the weights of the former would have increased. It seems reasonable to assume that they would. Paired feeding experiments would throw additional light on this question.

The value of the frozen crab meat protein was almost equal to that of beef protein as determined by Hoagland and Snider (8) in a similarly conducted experiment. They found that rats fed beef protein at a 10 per cent level gained, on an average, 2.5 grams for each gram of protein consumed. As mentioned above, the value found for both of the frozen crab meat proteins was 2.3 grams. Suzuki, Matsuyama, and Hashimoto (19), as mentioned in the literature review, found the protein of "talapa" crab to have nearly the same value as beef protein.

Summary

1. The literature on the composition and nutritive of crab meat is reviewed.

2. The sand crab, *Platyonichus ocellatus,* and the value blue crab, *Callinectes sapidus,* are very similar in chemical composition and in food value.

3. Crab meat may be described as a high protein food, high in mineral content and alkalinity, and of medium calorific value.

4. The copper and iodine contents are especially significant, while calcium, phosphorus and iron are also present in large amounts. The ash is particularly rich in potassium, to which it owes its high alkalinity.

5. Rat growth tests, based on weight gains per unit weight of protein consumed, show a high biological value for the proteins of both species of crabs. The crab protein is definitely superior to casein when compared in this way where the crab meat and the casein served as sole sources of protein in the diet. Crab protein has about the same biological value as beef.

6. The canned blue crab is slightly inferior to the frozen meat in growth promotion. Freezing has no effect on the nutritive value of the crab proteins.

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STATISTICS ON THE PRODUCTIVITY OF INLAND WATERS: THE MASTER KEY TO BETTER FISH CULTURE

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Nature strives to maintain a balance between the aquatic community and adjacent land communities. Normally this inter-relationship is finely adjusted, and, over a period of years, in a given lake or stream and its watershed, this balance is more or less constant, although marked fluctuations may occur.

Any constituent organism of the aquatic community at any given time may be termed its *standing population* or *standing crop*. The standing crop of any constituent, intermediate or end product of the cycle, may yield part of itself to the land, to be replaced again by the working up of organic matter of lower orders in the food chains. That part of the standing crop which is reclaimed by the land communities may be termed the *total yield*. That part which remains in the water to reproduce and die and thus participate in the aquatic turnover may be termed the *residual population*. That portion of the total yield which is utilized by man may be defined as the *economic* or *commercial yield* (this includes that taken primarily for sport). In this paper the term *yield* will be used as synonymous with *commercial yield* unless otherwise qualified.

The problem of the fish culturist consists not only in the proper control, to his own advantage, of the biological activities which take place in the water, but in the control of the entire land-water-yield cycle. The residual population in a given water area, unless unbalanced by abnormal natural or human disturbances, is more or less constant. To attempt to increase this residual population beyond the biological limits set by nature, by planting more fish, is in itself a serious disturbance which may derange the biological balance and reduce the very species we intended to increase. Restocking, in my opinion, is justified only when the residual population of a species is reduced, by overfishing or otherwise, to a point where it not only cannot maintain itself, but cannot produce an excess or yield commensurate with the food producing capacity of the environment.

Given a sufficient residual population, the yield of any constituent of a biologically balanced community can be increased only in direct proportion to the amount of organic matter that is added from the land in the form of fertilizer or food without deranging the natural balance. Knowledge must be acquired, especially in the case of end products, of the minimum number of individuals of each species per given area required in a residual population for reproductive purposes and the maximum beyond which overstocking will result in a diseased or dwarfed population. We must also accumulate statistics on the standing crops, the annual turnovers of residual populations, and the yields of

various types of natural and controlled aquatic communities. Before this is done we cannot even remotely anticipate the ultimate possibilities of American aquiculture.

The gathering of accurate statistics on the yields of waters is attended by many difficulties. Even in the case of impounded waters, figures are lacking, especially in America where commercial fish farming of pond species is as yet an infant industry. Such figures as are available are frequently impossible of use in comparisons as some refer to standing crops; some to commercial yields gathered from concentrated areas and may or may not take into consideration the intervening, less-productive areas from which the food supply is drawn; some refer to the total yield, including species of little or no commercial value; whereas others refer to the salable or usable portion of the crop; finally, in submitting figures, some authors either do not mention or do not take into consideration the time interval during which the crop has been developing. Miscellaneous observations, however, point to a normal productivity per acre of fish and other aquatic life of commercial value that is at least equal to and often in excess of the production of beef or pork. The average annual production of beef on cultivated land has been calculated at about 142 pounds per acre and of pork at about 300 pounds per acre (James).

In analyzing the figures that are quoted in the following table, one cannot venture to predict similar results on any corresponding project. The figures are given merely to show possible yields. An assortment of species with different habits will generally give greater productivity than a single species or an assortment with similar habits. There is no universal rule, however, and one's increasing control over the biological cycles involved is predicated upon the use of brains and the development of technical skill just as in any other industry.

In the following table (Table 1) the writer has made a summary of quantitative data on the production of natural waters and fish ponds.

The data of Birge (1929) on Lake Mendota is of particular interest in its relation to the fish production. He found that the standing crop of minute algae in the plankton of Lake Mendota, Wisconsin, averages about 3,000 pounds per acre. The annual turnover is estimated at several tons. The standing crop of small live crustacea in the same lake is placed at 200 pounds per acre, and the annual turnover at about 2,000 pounds. To this may be added a 1,000 pound turnover of insect larvae and insects. In spite of this high productivity of food organisms, the standing crop of yellow perch in the same lake would not greatly exceed twenty pounds per acre and the annual crop harvested by anglers perhaps does not exceed ten pounds per acre (Pearse and Achtenberg 1920).

It should be noted that both stream and lake species give much higher yields in warmer climates when the organic storage capacity is greater and the turnover is much more rapid. On the basis of prelimi-

TABLE 1

Place	Authority	Kind	Standing Crop, Pounds Per Acre	Annual Yield, Pounds Per Acre	Remarks
Lake Mendota, Wis.	Birge (1929)	plankton algae	3,000		
Lake Mendota, Wis.	Birge (1929)	plankton crustacea	200	2000*	
Lake Mendota, Wis.	Pearce and Achtenberg (1920)	perch	20*		
Norway lakes	Dahl	trout		3.5	lakes without other fish
Norway lakes	Dahl	trout		175	lake with other fish
German and English lakes	Dahl	fish		15 to 40	
Small Illinois streams	Thompson and Hunt (1930)	fish	150	10 to 20	
Illinois glacial lakes and rivers	Thompson and Hunt (1930)			25 to 75	
Spring-fed S. Louisiana streams	Viosca	fish	300-500		half fine fish
Spring-fed S. Louisiana streams	Viosca	bass and sunfishes		100	
Borrow pit, St. Tammany Parish, La.	Viosca	edible fish	760		
Borrow pit, St. Tammany Parish, La.	Viosca	all fish	860	400	
Louisiana waters (1931)	Fiedler (1933) and Viosca	fish, frogs, crayfish, etc.		30	
Lake St. John, La. (1928)	Viosca	commercial fish		200	valley lake
Illinois River, lakes and ponds, (1908)	Alvord and Burdick (1915)	commercial fish		186	valley lakes and ponds
Illinois River, lakes and ponds, other years	Alvord and Burdick (1915)	commercial fish		100	valley lakes and ponds
Lake Senachwine, Illinois	Thompson[1]	fine fish		50	valley lake
Lake Senachwine, Illinois	Viosca	commercial fish		150	valley lake
Illinois River system, lakes (Copperas Creek to Havana)	Richardson (1921)	weed and bottom animals	1447		valley lake
Illinois River system, lakes (Copperas Creek to Havana)	Richardson (1921)	animals	705		river itself
Oneida Lake (0-6 feet)	Baker (1918)	animals	387		sand bottom
Oneida Lake (0-6 feet)	Baker (1918)	animals	207		gravel bottom
Oneida Lake (0-6 feet)	Baker (1918)	animals	188		clay bottom
Oneida Lake (0-6 feet)	Baker (1918)	animals	210		clay and sand bottom
Oneida Lake (0-6 feet)	Baker (1918)	animals	230		mud
Illinois glacial lakes (0-6 feet)	Richardson	animals	105		
Lake Mendota, Wis. (one meter)	Muttkowski (1918)		60		
Lake Mendota, Wis. (three-meter zone)	Muttkowski (1918)		64		
Illinois River lakes	Viosca	commercial and game fish		288	
Lake Pepin (Mississippi River lake)	Coker (1929), Fiedler (1933)	commercial fish		55	aver. over several yrs.
Lake Keokuk (Mississippi River lake)	Coker (1929), Fiedler (1933)	commercial fish		25	aver. over several yrs.
Fourteen Japanese lakes	Tokuhissa	commercial fish		108	average
German lake	Alvord and Burdick, 1915, p. 82	all fish		1,517	
Unfertilized ponds (north of Maryland, Kentucky and Missouri)	Embody[1]	fish		300	

TABLE 1 (Continued)

Place	Authority	Kind	Standing Crop, Pounds Per Acre	Annual Yield, Pounds Per Acre	Remarks
Fertilized ponds (northern United States)	Embody (?)	fish		500	
Fertilized pond, Fairport, La.	Davis and Wiebe (1930)	bluegill sunfish		282	
Farm pond without fertilizer, Fairport, La.	U. S. Bureau of Fisheries	fish		104-440	(1922-1924)
Fertilized pond, Fairport, La.	U. S. Bureau of Fisheries	bluegill sunfish		272	
Unfertilized pond, Fairport, La.	U. S. Bureau of Fisheries	bluegill sunfish		188	
Kansas one-acre pond	Dyche (1914)	mostly game fish		2,027	art'fl food supplement
Concordia fish culture station	Viosca (1929)	bass and sunfish		800	
German fish ponds, unfertilized	Alvord and Burdick (1915)	carp		100-348	good soil
German fish ponds, fertilized with Muenchen sewage	Schillinger (1928)	carp		1000	
Small shallow German ponds with inflow from rice fields (also fertilized with sewage)	Bushkeil (1932)	carp		892	
Large German ponds fertilized with manure and rice threshings	Bushkeil (1932)	carp		1,338	
South China ponds	Albert W. Herre[1]	milkfish (bangos)		1,000 to 13,500	3,990 high average
Japanese rice fields	Honda (1935)	carp		294	8-yr. nationwide aver.
Japanese reservoirs and marshes	Honda (1935)	carp		221	8-yr. nationwide aver.
Japanese breeding ponds	Honda (1935)	carp		1464	8-yr. nationwide aver.
Japanese rice fields	M. Tokuhisa[1]	yearling carp		168-236	
Japanese rice fields	M. Tokuhisa[1]	yearling carp		236-506	art'fl food supplement
Japanese rice fields	M. Tokuhisa[1]	second year carp		270-573	art'fl food supplement
Japanese breeding ponds (running water)	M. Tokuhisa[1]	carp		1012-3373	artificially fed silk worms, wheat, barley, earthworms
Japanese ponds at Kobe	C. Uchida[1]	eels		3,333	fed silk worm pupae
Japanese reservoirs, marshes, etc.	Honda (1935)	eels		191	8-yr. nationwide aver.
Japanese cultivated ponds, artificially fed	Honda (1935)	eels		2285	8-yr. nationwide aver.

[1] Personal communications.

nary quantitative investigations, I would estimate the total standing crop of all species in spring-fed creeks in South Louisiana to be somewhere between 300 and 500 pounds per acre, about half of which are fine fish. On the basis of Thompson's estimates for Illinois, I might venture a guess that the turnover of fine fish in these Louisiana streams, mostly spotted smallmouth bass and various sunfish, is not less than 100 pounds per acre per annum. There are no data available as yet upon which to base the total or economic yields. It is evident, however, that within certain limits, increased angling will speed up the aquatic cycle and increase the yield. Whether or not 100 pounds per acre could be removed annually from these streams without upsetting the balance remains to be determined. Until such investigations are put upon a quantitative basis, however, I would not recommend the building of a single hatchery, or even the planting of a single fish.

A few years ago (May, 1929) the writer passed a trammel net through a roadside borrow pit in northern St. Tammany Parish, Louisiana. This area of standing water was almost exactly one-tenth of an acre and graduated to three feet at its deepest part. It is comparable to a side pool in a small stream for it has a connection to such a stream through roadside ditches which go dry between showers. All fish which did not pass through a one-half inch square mesh were caught and weighed. The fish of edible size, consisting of largemouth bass, sunfish and bullheads, weighed seventy-six pounds or at the rate of 760 pounds per acre. Adding to this ten pounds of undersized fish which did not escape, we have a standing crop of all species combined of at least 860 pounds per acre. The probable yield of such a pond, on the basis of fragmentary knowledge, could perhaps be estimated roughly at a rate approaching 400 pounds per acre per annum. Although no other figures are available on the productivity of small natural ponds this far south, miscellaneous observations would point to a value substantially greater than that for unfertilized ponds in colder climates.

Turning our attention to larger areas, if we take the productivity of all fresh waters of the state of Louisiana, we find, according to statistics furnished by the U. S. Bureau of Fisheries (Fiedler, 1933) that the marketed yield during 1931, the last year for which federal statistics are available, was over nineteen million pounds. If we add to this another million, a very conservative figure for fish, frogs, crawfish, etc., taken by sportsmen and others for home consumption, we have a total of not less than twenty million pounds. The area from which this is gathered, including the adjacent swamps, is roughly two million acres, thus giving a statewide yield of about ten pounds per acre, per annum. The swamps and marshes produce mainly food for the other waters, but they are included in the above total even though they constitute a far greater area than the open waters themselves. If we exclude the swamps and marshes, and give due credit for their production which is mainly frogs and crawfish, we have a marketable yield for the open waters of Louisiana of perhaps thirty pounds per acre per year.

Lakes, when considered separately from the streams to which they are connected, usually produce still higher yields. Good lakes in rich valleys average about 150 pounds per acre per year of commercial fish alone. From Lake St. John in Concordia Parish, Louisiana, with an area of approximately 2,000 acres, there were marketed during ten months during 1928, 402,000 pounds of commercial fish or over 200 pounds per acre, these being secured by seining alone. These figures were gathered by the Concordia Parish Game and Fish Commission which collected a severance tax on that poundage from the party holding the contract to seine the lake. In that instance the size limit was higher than required by state law and the contract holder maintained that as a result of the special restriction, over fifty per cent of the poundage that would have been available under the state law was returned to the waters alive. This does not take into consideration the fine fish caught by anglers, the yield of which is very high in Lake St. John and would increase the above figures considerably. Unfortunately no statistics are available as to the sportsmen's catch in that lake.

Various investigators have shown that the fish productivity of waters is dependent upon the sources of food supplies, these in turn being dependent upon the dead and living organic matter existing in or entering the water from outside sources. Robert E. Richardson (1921) states that the productivity of combined weed and bottom animals occurring in lakes of the Illinois River System between Copperas Creek and Havana averaged 1,447 pounds per acre as compared to 705 pounds for the unusually rich sections of the river. Thus, the weedy margins of the shallower lakes of the Illinois River System are richest in the crop of small animals (insect larvae, snails, etc.) which are harvested by fishes and the poorest sections are in the river channel itself which is swept constantly by the current and kept comparatively bare. The sluggish portions of the river are richer than the swifter sections. In the richest part of the system above Havana, Illinois, where the combined inshore and bottom fauna of the lakes averages in weight about twice as much as that in the river, the highest yield in fishes is produced.

Glacial lakes without appreciable outside sources of organic matter are much poorer than the lakes of the Illinois River System, for example, with the rich sources of organic matter derived from the Chicago drainage canal and the prairie soils of central Illinois. The bottom muds in lakes, because of their greater storage capacity for nitrogen and other organic matter than those in rivers, have a richer fauna as a rule. Furthermore, in the lakes, the muds of the marginal waters are richer in organic matter than those of the deeper areas, traceable no doubt to higher temperatures, greater amount of sunlight, and more profuse plant growth, the decay of which enriches the soil. The vegetation here as elsewhere occurs in great abundance along the shallow

margins of lakes down to the four-foot contour line, and in lesser abundance to the six-foot contour line.

Richardson has shown further that the nitrogen content in the river sediments is many hundred times the nitrogen content of the flesh of the animals living in these sediments and the total dry weight of this organic matter is several thousand times the dry weight of the bottom fauna. All oxidizable matter, whether dissolved or suspended in the water, can be regarded as a potential source of food for the micro-organisms which in turn are eaten by the bottom and weed fauna. The plankton of such bodies of water as Thompson Lake per cubic volume of water was found to be greater at any given time than that of a given volume of river water. This plankton is sufficient in either case to feed a vastly richer bottom and weed fauna than is found in the river or lakes.

This and other evidence analyzed by Richardson shows that lakes are better producers of fish foods over their acreage than rivers, and that their richest fauna is developed near the shores in the weedy zones where the largest deposits of organic matter are found. The lakes likewise are the greatest producers of fish flesh.

It is generally assumed that the average weight of animal food consumed in producing a pound of fish flesh is about five pounds. Applying this five to one feeding ratio to the stocks of unconsumed bottom and weed animals in the Illinois River System, Richardson arrives at a hypothetical fish yield of 141 pounds per acre for the river and of 423 pounds per acre for weedy lakes. For total lake acreage the hypothetical yield is 289 pounds, about twice the river average, and for the river and lake acreages combined, 260 pounds. The actual commercial catch in the district during 1908 was 178 pounds. Fifty pounds of fine fish added to this would bring the total yield up to 228 pounds, leaving still a hypothetical balance of thirty-two pounds which I presume is consumed by kingfishers, water snakes, turtles, darkies, and what not. As Richardson does not take into consideration the terrestrial organisms or products consumed directly by the fish, the hypothetical yield of 228 pounds can still be increased by a factor as yet unknown.

Such data as these are extremely valuable because of their bearing on pondfish culture where natural feeding is resorted to. They throw light on the reasons why bass and sunfish thrive in shallow weedy ponds and lake shore margins. A duplication of such conditions is good practice in nursery ponds, provided judgment is used in selecting the most suitable types of pond weeds. They also show why better yields are produced in ponds without outlets than in ponds with a constant overflow, flowing water being not nearly as productive as still water when there is a biological cycle involved. In flowing water, for example in trout culture, a high productivity can only be produced by artificial feeding and if we consider the area upon which this food (sheep liver, beef hearts, etc.) is produced, the productivity of fish

flesh per acre involved would certainly not be higher than that of still water ponds. A pond with a flow of water through it is comparable to a pool in a stream and both the fertilizer and the plankton developed therefrom is constantly lost at the overflow. A pond without an overflow is comparable to a natural lake where the biological cycle assumes its natural course without interruption, except that in a pond we can pre-determine most of the species involved, and stimulate the biological processes by the addition of organic matter in the form of suitable fertilizers.

Although we cannot expect to achieve anything approaching the Japanese maximum yields in pond culture of American warm water game fishes, it would seem, judging by the figures available, that we have hardly made a beginning. I believe that no material progress in this direction will be made until American fish culture is put on a quantitative statistical basis. We must add materially to our fragmentary knowledge of standing crops and include knowledge of all constituents of the manifold types of aquatic cycles, of the residual populations and aquatic turnovers, and of the extent of the organic interchange between land and water areas in addition to the purely commercial yields. Such statistics constitute the master key to secrets of nature long hidden in "little drops of water" and under "little grains of sand," secrets which, when revealed, will enable us to break away at last from the American policy of raising fry and not fishes, numbers and not pounds. If this paper stimulates thought in that direction, it will have served its purpose.

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THE NUTRITIONAL REQUIREMENTS OF TROUT

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The following paper is a review of the more important nutritional experiments conducted at the Cortland Experimental Hatchery during the last two years. The set-up of our troughs and the general program of the experimental work are the same as we reported in 1933. Some changes have been made in the technique of conducting the experiments and are described hereinafter.

THE CALCIUM REQUIREMENT OF TROUT

One of the problems confronting the fish culturist is that of producing trout equal in strength and vitality to those growing under natural conditions. At present there are very few methods available for testing the strength and vitality of artificially reared trout or of trout growing under natural condition. One way that this problem may be approached by the laboratory is by observing the development of trout skeletons.

Several years ago (1931) we presented data showing the calcium and phosphorous content of trout bodies reared artificially upon diets high in calcium and others reared upon low calcium diets. From these experiments we found that trout fed low calcium diets stored as much calcium in their bodies as trout fed diets high in this element. It was evident that the low calcium diets fed the trout did not contain enough of this mineral to account for that stored in the body and they must have obtained the additional calcium from some source other than their diet. We concluded that the only other source from which they could obtain this was from the water in which they were reared.

More recently, we devised an experiment to measure the relative amounts of calcium that trout obtain from the water and from their diet. Three groups of fingerling brook trout, containing fifty individuals each, were placed in separate troughs supplied with independent sources of spring water. The water ran through a screen, thus preventing any entrance of natural food. The trout were fed beef liver for five days at the end of which time twenty-five trout were taken from each group, killed, and placed in separate jars containing ninety-nine cubic centimeters of ethyl alcohol and one cubic centimeter of concentrated hydrochloric acid. In the meantime a series of jars had been filled with a known amount of ground beef liver preserved in alcohol. The remaining twenty-five fish in each group were then fed this preserved liver for the next twelve weeks in amounts that they

would clean up at each feeding. The amount of food eaten by each of the three groups during the experiment was determined by difference. At the end of this experiment the three groups of trout were killed and placed in three separate jars with preservative. Trout that died during the course of the experiment were preserved and combined with those remaining at the end, giving twenty-five fish for final analysis in each group. Samples of water were taken each day during this period and preserved in paraffined bottles. The six jars containing the preserved trout, the preserved liver, and the combined samples of water were then dried and analyzed for calcium.

At the beginning of the experiment the mean weight in each group was 3.6 to 3.8 grams and at the end of the twelve week period it was 4.4 to 4.6 grams. As a result of this poor growth we expected the experiment to fail, but quite the reverse happened. Although the trout bodies made very little growth, the skeletons must have continued to grow as the data in Table 1 showed that a considerable amount of calcium was stored. It has been known for some time that the apparent growth in weight of some higher animals can be retarded with a continuation of growth of the skeleton.

The summarized analytical data are given in Table 1.

TABLE 1.—THE ABSORPTION OF CALCIUM (Ca) FROM THE DIET AND WATER BY BROOK TROUT

Experiment No.	Mean weight at beginning (grams)	Mean gain in weight of live trout per 12 weeks (grams)	Ca in 25 fish at start (Mgs.)	Ca in 25 fish at end (Mgs.)	Difference equals Ca stored in three months (Mgs.)	Ca stored per trout (Mg.)	Raw liver fed for three months (grams)	Ca fed in liver (Mg.)	Ca taken from water containing 43 mg. per liter (Mg.)
56	3.8	0.5	360.3	495.5	135.2	5.4	478	27.9	107.3
57	3.6	0.8	337.1	491.3	154.2	6.2	434	25.3	128.9
58	3.7	0.9	368.6	516.7	148.1	5.9	488	28.5	119.6

The water during this period contained forty-three milligrams of calcium per liter. Therefore each trout must take an amount of calcium from the water each day equal to that contained in one to two cubic centimeters of the water. This experiment shows clearly why we have failed to produce any disease resembling rickets in trout when we fed diets low in calcium and high in phosphorus. Our experiments do not indicate whether this calcium is absorbed through the gills or from the gastro-intestinal tract.

All analyses were run by Mr. H. S. Osgood, using the method of Morris et al., described in Analytical Edition, "Journal of Industrial and Engineering Chemistry," 1931, page 164. The liver was ashed by the wet method using concentrated nitric acid and perchloric acids. When the volume had been reduced to about five cubic centimeters, an additional ten cubic centimeters of concentrated hydrochloric acid was

added. The volume was again reduced to five to ten cubic centimeters, four to six cubic centimeters of saturated sodium carbonate solution added. The solution was then made to a volume of one hundred cubic centimeters and an aliquot taken for calcium determination.

These data confirm directly the conclusions we drew from earlier analytical data (1931). They show the importance of the calcium in the water supply. They also show why it might be essential to feed a source of calcium in case hatchery waters are poor in this element. They show the need for calcium analyses upon the various hatchery waters.

The Digestion and Utilization of Fat by Trout

In 1933 we presented a report which included data and discussion on the utilization of fats by trout. In brief, the experiments were as follows. Two groups of trout were fed a basic diet composed of equal parts beef liver, cottonseed meal and dried skim milk. For one group of trout, 25% of cottonseed oil (Wesson) was added to the basic diet, and the other group received the same basic diet plus 25% of hydrogenated cottonseed oil, "Crisco". At the end of thirty-two weeks both groups had made the same rate of growth indicating that either both of the fats were absorbed or that neither were utilized at all. We endeavored to test this by making a third group and feeding them the basic diet without the supplement. One-third of each of the groups fed the two fat-containing diets were pooled to make the new group and were fed three-fourths as much food, since there was no fat in the diet and since the fat content of the other diets was 25%. The three experiments were continued for twenty weeks at the end of which time it was evident from the growth curves that the new group receiving no fat and fed three-fourths as much feed as the others had made about the same rate of growth. This led us to believe that it was possible that neither of the fats were digested although it was realized that the question of fat digestion should be settled by direct metabolism studies.

In view of the results of the metabolism studies described later in the present paper it seems clear that this earlier tentative conclusion is in error. While the trout fed a diet without fat, though receiving less food, grew as well as those receiving diets with fat, it now appears from studies in progress that all of the groups were receiving more food than they needed. Preliminary observation of these studies, designed to determine the most economical amount of food to feed trout of different sizes at our water temperature, 47° ±0.5° F., indicate that when trout are overfed, not only is food wasted but that also growth itself is curtailed. This observation suggests that the groups receiving the fat in the previous experiments were actually at a disadvantage and that the excessive amount of food offered nullified the object of the experiment insofar as the utilization of the fat was concerned.

Furthermore, after the earlier report was written, we obtained some proof that the fat in the diets was actually being deposited in the trout bodies even though our growth curves indicated no fat utilization. Since the body fat of animals tends to resemble the fat of its feed to a certain degree, and since the iodine number of the depot fats reflect the degree of unsaturation of the fat fed, we determined the iodine numbers upon pooled samples from six trout from each of the experimental groups. The samples from the males and the females were run separately. The fat samples were taken from the mesentary depots. We have summarized the results of these investigations in Table 2.

TABLE 2.—IODINE NUMBERS OF THE DEPOT FAT OF BROOK TROUT FED DIETS CONTAINING FATS

Kind of Fat in Diet	No. of Trout	Sex	Iodine No.
Cottonseed oil (Wesson)	4	Male	109
Cottonseed oil (Wesson)	2	Female	100
Hydrogenated cottonseed oil (Crisco)	3	Male	95
Hydrogenated cottonseed oil (Crisco)	3	Female	90
*No fat in diet	2	Male	89
*No fat in diet	4	Female	100

*The fish for this group were taken from the two groups receiving fat in their diets, eighteen weeks prior to this determination.

Since the fish fed the diet containing the cottonseed oil have higher iodine numbers than those fed the diet containing the hydrogenated oil, it indicates there is a difference in the quality of the body fat. This difference is in the direction that would result if some of the fats in each diet were absorbed and deposited. Therefore there must have been some utilization of each of these fats.

Chemical Balance Studies With Fat

Last year we were able to purchase apparatus necessary to carry on metabolism studies. One important part of such equipment was an air compressor such as that used at garages for the inflation of automobile tires. This was used to force compressed air through carborundum blocks into aquaria set in troughs in running water. The carborundum blocks served to break the air into very fine bubbles. The running water in the troughs kept the water in the aquaria at its own temperature. The aquaria used for the yearlings measured 12 x 24 x 12 inches and those used for fingerlings measured 8 x 12 x 8 inches. The yearlings were held in thirty liters of water and the fingerlings in nine liters of water. The trout were first allowed some time to acclimate themselves to the aquaria and were then placed on the diets used in the fat metabolism studies.

The fat metabolism studies were devised for the purpose of determining whether or not trout could digest and utilize such oils as cottonseed oil and salmon oil, and a hard fat such as hydrogenated cottonseed oil. It was also desired to measure the relative digestibility of these fats by trout of two different sizes and ages.

The metabolism trials extended over a period of ten days. The feed was weighed carefully before it was fed. The trout were allowed a feeding period of twenty minutes, daily in the case of the yearlings and twice daily for the fingerlings.

After the feeding period, as well as just before the feeding period, the water was changed in the aquaria. The water in each case was strained through several thicknesses of cheese cloth. A definite fraction of this solution, an aliquot, was saved for analysis. The same cheese cloth was used throughout the experimental period of ten days and when not in use was kept in a preservative.

By use of charcoal markers it was found that feed passes through yearling trout in about thirty-six hours and through fingerlings in about twenty-four hours when they are held in aquaria. For this reason ten-day experimental periods were considered adequate for studying the digestibility of fat.

Brook trout (*Salvelinus fontinalis*) were used in all digestion trials. The water temperature was 8° C. (47° F.) in all trials.

The basic diet consisted of a mixture of equal parts of cottonseed meal, fresh beef liver and dry skim milk. In experiments 1-8 (inclusive), three parts of this basal diet were mixed with one part of the special fat on the basis of weight. In Nos. 9-16 (inclusive), seven parts of fat were mixed with ninety-three parts of this feed. Samples of this fresh beef liver, cottonseed meal and skim milk were preserved for analysis. After drying, they were subjected to extraction with alcohol and ether in turn, in order to find their content of fatty acids and total lipids by the same method as that used for the other analyses.

The water samples were preserved in sealed bottles by the addition of a few drops of chloroform and ether. The cheese cloth and solid material were preserved by the addition of ether and chloroform. At the end of each experimental period of ten days there were four samples for analysis from each aquarium, (1) the cheese cloth and unconsumed feed residues (2) the cheese cloth and solid excreta (3) an aliquot of the water and liquid residues from feed (4) an aliquot of the water and liquid residues from excreta.

In the laboratory, samples Nos. 1 and 2 were first filtered on a suction funnel. The residue and cloth were then partly dehydrated by soaking in redistilled 95% ethyl alcohol. This was then filtered off and the residue transferred to a suction funnel. These filtrates were combined and evaporated on the steam bath to a low volume. The solid residue and cloth were then placed in a continuous extractor and extracted with alcohol for six to eight hours. The alcoholic extract was then combined with the other filtrates. The extractor was then filled with ether and run for two to four hours. This ether extract was then concentrated with the other filtrates.

The liquid samples were concentrated to very low volumes on the steam bath. All samples were then saponified with potassium hy-

droxide and the fatty acids and the nonsaponifiable fraction determined in the conventional manner.

These extracts treated with potassium hydroxide and concentrated to a very low volume on the steam bath, were then made to a volume of five hundred cubic centimeters with hot water. In some cases these were heated a number of hours in order to get a homogeneous solution. One twentieth of the total volume was removed for an aliquot. This was transferred to a one hundred and fifty cubic centimeter fat flask and taken to dryness on the steam bath. The residue was taken up in six cubic centimeters of hot water and eleven cubic centimeters of ethyl alcohol. This was then treated with four cubic centimeters of concentrated hydrochloric acid and transferred to a Rohrig tube. The remainder of the extract was then made in the same manner as the fat determination in the Roese-Gottlieb method.

The mixture of fatty acids and unsaponified material was weighed after driving off the ethers and drying in a vacuum oven. The lipid materials were then dissolved in petroleum ether and extracted with aqueous potassium hydroxide to remove the fatty acids. This was followed by three washings with water, in the extraction funnel. The petroleum ether was removed on the steam bath. The samples were dried again and the fatty acids determined by difference.

The water samples were treated in the same manner except the entire residue was used instead of an aliquot.

The total fat in the water from the excreta varied from 0.3 to 5.3 grams while that in the solid excreta varied from 0.3 to 2.5 grams.

By these methods the total fat of the basal diet of equal parts of fresh beef liver, cottonseed meal and dry skim milk proved to be 5.23%. Separate duplicate analyses were run upon samples of the three fats and the following recoveries were made: "Crisco" 96.7%, cottonseed oil (Wesson) 98% and salmon oil 98.6%.

The total fat in every case was obtained by first multiplying the fatty acids by the factor 1.047. This value for the triglycerides was then added to the nonsaponifiable to give the value for the lipids. In this study the fatty acids alone could have been considered without much error in final results since the fats studied were largely triglycerides.

In Table 3 are summarized all pertinent data from these digestion trials. In each case four of these ten-day digestion trials were run at the same time. They are designated by the same letter after the experiment number.

In every case the oil was better digested than the hydrogenated fat "Crisco." It will be recalled that this fat melts at about 43° C. while the body of the trout is conducting the digestion at a temperature of 8° C. No real difference exists between the digestion and utilization of the cottonseed oil and the salmon oil. Both are liquid at 8° C.

TABLE 3.—THE UTILIZATION OF COTTONSEED OIL, HYDROGENATED OIL (CRISCO) AND SALMON OIL BY FINGERLING AND YEARLING BROOK TROUT *(SALVELINUS FONTINALIS)*

Experiment No.	No. trout used	Weight beginning (grams)	Weight end (grams)	Feed allowed (grams)	Fats ingested (grams)	Fats excreted (grams)	Fats utilized (grams)	Form of fat added	Per cent level of fat included in diet	Per cent total lipid utilized
1-A	6	480	530	140	35.0	2.7	32.3	Cottonseed oil	25	92
2-A	6	480	495	140	25.2	7.0	18.2	Crisco	25	72
3-A	50	115	125	60	10.4	1.2	9.2	Cottonseed oil	25	88
4-A	50	115	128	60	9.6	2.1	7.5	Crisco	25	77
5-B	6	600	632	180	26.8	2.0	24.8	Salmon oil	25	93
6-B	6	560	610	180	28.3	4.3	24.0	Crisco	25	85
7-B	50	170	196	90	18.4	1.0	17.4	Salmon oil	25	94
8-B	50	185	212	90	8.7	1.9	6.8	Crisco	25	78
9-C	6	620	658	180	9.4	1.3	8.1	Cottonseed oil	7	86
10-C	6	610	628	180	11.2	2.9	8.3	Crisco	7	74
11-C	50	210	218	100	5.2	.7	4.5	Cottonseed oil	7	88
12-C	50	200	233	100	5.7	2.7	3.0	Crisco	7	53
13-D	6	658	686	200	14.6	1.9	12.7	Salmon oil	7	87
14-D	6	628	662	190	9.1	4.8	4.3	Crisco	7	47
15-D	50	218	247	110	7.5	1.4	6.1	Salmon oil	7	81
16-D	50	233	258	115	6.2	3.2	3.0	Crisco	7	50

These data indicate that there is nothing of specific merit in a fish oil as a fish feed as far as the available energy is concerned. Trout digested the oil of a plant origin as readily as that from fish. The melting point of the oil or fat is the essential characteristic.

The amount of the hydrogenated fat that was digested is surprising, however, when the body temperature and the short intestinal tract of the brook trout are considered.

About the same per cent of these fats seem to be utilized by trout when the level in the diet is 25% as when this level is 7%. If the effect of the fat in the basal diet is considered, it is found that the utilization of the added fat such as "Crisco" is a few per cent lower.

The size of the trout in these studies had no effect. Fat is digested to about the same extent by trout weighing 2 grams and those weighing 100 grams.

These data indicate that trout digests even oils to a less degree than men. However, the data which indicate that more than 95% of fats that melt at 43° C. or lower are utilized in the human body, are based upon relatively short digestion periods and may also be subject to variations in relation to the level ingested and the interplay of the other constituents in the diet. For this reason the digestion of fats by a cold blooded species such as a trout cannot be compared too closely with the data available for warm blooded species.

In considering these data and their application in the hatchery, it may be well to recall that lard melts at 43° C., which is about the same as the hydrogenated fat, "Crisco," used in these studies. On the other hand mutton tallow melts at 45-50° C. Since both fats are solid at the temperature of the trout body it is doubtful if they would vary much from "Crisco" in degree of utilization.

The Growth and Efficiency of Food Conversion of Four Trout Species

Several years ago (1933) we presented growth curves of three species,—brook, rainbow and brown. Since the fish on these experiments were started at different weights and ages, it was decided to start new groups using fry just ready to begin feeding. These new groups were approximately the same age at the start, but the mean weights of the different species of fry were not the same due to inherited characteristics of the strain used of the different species, size of eggs, etc. In addition to the above mentioned species. lake trout were also started. The four species were held for the first six months of the experiment in small troughs and then transferred to deep tanks. A description and diagram of our experimental troughs may be found elsewhere (McCay, 1932).

During the first thirty-two weeks of the experiment, we removed a few fish at four week intervals in order to obtain the mean dry weights. Throughout the studies we removed fish from the ex-

periment in order not to have over-crowded conditions which would prevent maximum growth. The mortality curves, Chart 1, show these removals by vertical drops in the curve.

The data from the determinations of dry weight during the early stages of the experiment may be found in another report (McCay and Tunison, 1933). Suffice it to say here that the growth curves from the dry weight data of the four species parallel the wet weight curve presented in Chart 1.

The environmental conditions were the same for all groups. The water temperature remains 47 ± 0.5° F. summer and winter. The diet consisted of two-thirds beef liver and one-third skim milk. The trout received amounts of the diet in proportion to their body weight, less being allowed as they grew larger.

Chart I.—Growth and mortality curves for four trout species, lake (39), brown (40), rainbow (41) and brook (42) fed similar diets of fresh beef liver and dry skim milk. Water temperature 47 ± 0.5° F.

NO.	AVERAGE GAIN, IN % OF BODY WEIGHT, FOR 16 WEEK PERIODS						
39	59	56	20	27	24	14	13
40	48	42	18	26	27	12	22
41	55	48	23	28	21	10	14
42	79	41	19	25	22	14	13

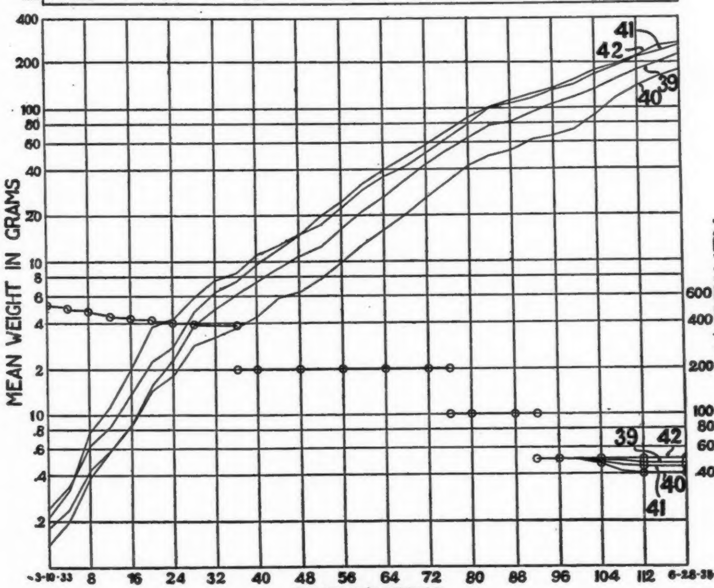

TABLE 4.—THE RELATIVE EFFICIENCY OF FOUR TROUT SPECIES TO CONVERT FOODSTUFFS INTO BODY TISSUES

Diet Number Species of Trout	39 Lake	40 Brown	41 Rainbow	42 Brook
Mean grams of dry feed to produce one gram of live trout first 40 weeks	3.06± .25	5.14± .56	3.47± .44	4.73± 1.21
Range	1.73—4.82	2.53—8.65	1.65—6.76	1.88—15.03
Mean cost to produce one pound of live trout first 40 weeks, in dollars	.53± .04	.90± .10	.61± .07	.83± .21
Range	.30— .84	.44—1.51	.29—1.18	.33— 2.63
Mean grams of dry feed to produce one gram of live trout 40-92 weeks	2.35± .13	2.84± .27	2.54± .20	2.51± .18
Range	1.43—4.11	1.97—6.90	1.66—5.43	1.50— 4.30
Mean cost to produce one pound of live trout 40-92 weeks, in dollars	.41± .02	.50± .05	.44± .03	.44± .03
Range	.25— .72	.34—1.21	.29— .95	.26— .75
Mean grams of dry feed to produce one gram of live trout 92-120 weeks	3.10± .18	4.33± .49	3.84± .24	4.04± .70
Range	2.32—4.54	2.85—8.40	2.89—4.95	2.38— 9.96
Mean cost to produce one pound of live trout 92-120 weeks, in dollars	.54± .03	.76± .09	.67± .04	.71± .12
Range	.41— .79	.50—1.47	.51— .87	.42— 1.74

The growth curves of the four trout species, lake (***Cristivomer namaycush***), brown (*Salmo fario*), rainbow (***Salmo irideus***), and brook (*Salvelinus fontinalis*), are presented in Chart 1. They represent the growth of the average member of each group and the lines are drawn through the actual weights. Also included in Chart 1 are the gains in per cent of body weight for the four groups. These gains are given by 16 week periods and are the average of four four week periods. Although it is usually a poor policy to average per cents, it seems legitimate in this case since gains calculated by these figures correlate fairly close with the actual gains. As the curves and percentage gains indicate, the growth of the four species is nearly parallel after the thirty-second week. It will also be noted that as the trout get larger and older their rate of growth is less rapid. However, growth has not ceased during these 120 weeks. We hope to be able to continue these experiments indefinitely and determine at what point growth ceases. We have been very fortunate so far in that the mortality has been negligible in these groups.

Records of the feed intake have been kept and the efficiency of the four species to convert their food into body flesh is summarized in Table 4. These data have been divided into three groups since we wish in the future to summarize the conversion data by one year periods in order to conform to annual reports. The data for the first forty weeks of feeding concludes the period ending December, 1933. The next set of data is for the following fifty-two weeks. The third set of data is for the period starting December 1934 and ending June 28, 1935.

Table 4 shows that the four species made the best use of their feed during their second year. The poorer conversion in the first half of the third year may possibly be explained by the slower rate of growth, and the possibility that they were allowed too much food, although they were allowed only what they would clean up at each feeding. At our water temperature the lake trout convert more of their food into flesh than do the other species. The brown trout are the poorest converters.

Tests of Commercial Feed Combinations

In 1934 we conducted experiments to determine if we could duplicate our 1933 results using the same diets and set up, and using a different strain of brook trout. In our first experiments we used brook trout fingerlings from eggs obtained from the U. S. Fisheries Station at Pittsford, Vermont. In the experiment the second year the brook trout fingerlings came from eggs received from the U. S. Fisheries Station at Craig Brook, Maine.

The same brand of food stuffs were used both years namely, Dairyman's League Spray Process skim milk, Dehydrating Process Company white fish meal, Neptune Fish Products Company salmon egg meal, and 41% cottonseed meal obtained from a local feed

store. Table 5 shows the analysis of the feedstuffs. The composition of the diets is given in Table 6. The moisture, protein and cost of the diets, as well as of diets 39-42 are calculated and shown in Table 7.

TABLE 5.—ANALYSES OF FEEDSTUFFS

Feed	Per cent moisture	Per cent protein, wet basis	Cost per pound in dollars
Skim milk (spray process)	5.6	32.4	$0.065
White fish meal	10.5	54.5	0.024
Cottonseed meal	10.0	36.9	0.014
Salmon egg meal	9.3	38.9	0.120
Beef liver	72.3	19.3	0.100

TABLE 6.—COMPOSITION OF DIETS IN PARTS BY WEIGHTS

Diet Numbers (1933)	(1934)	Beef liver	Skim milk	Cottonseed meal	White fish meal	Salmon egg meal	Water added to diet in per cent by weight
110	73	15	29	28	28	----	85
111	76	15	29	28	----	28	90
113	77	15	29	----	28	28	85
114	74	50	25	25	----	----	50
115	75	50	----	25	----	25	44
116	78	100	----	----	----	----	----
101*	----	100	----	----	----	----	----
118*	----	15	29	28	28	----	85

*Experiment conducted in production hatchery.

TABLE 7.—MOISTURE, PROTEIN, AND COST OF DIETS (CALCULATED)

Diet Number	Per cent moisture	Per cent protein (dry basis)	Cost of diet per pound (dry basis) in dollars
110, 118	18.2	46.3	$0.054
111	17.9	40.6	0.086
113	18.1	47.0	0.090
114	40.0	44.8	0.116
115	40.9	48.3	0.142
116, 101	72.3	69.4	0.360
39-42	50.0	47.1	0.175

TABLE 8.—THE RELATIVE EFFICIENCY OF THE PRACTICAL DIETS LISTED IN TABLE 6. THE GROWTH OBTAINED FROM SUCH DIETS

Diet Number 1934	1933	Mean grams of dry feed per gram gain of live trout 1934	1933	Mean cost to produce one pound of trout, in dollars 1934	1933	Av. mortality-per cent per four-wk. periods 1934	1933	Av. gain-per cent per four-week periods 1934	1933
110	73	3.42±.22	5.35±.51	.19±.01	.29±.03	2.39	0.10	44	30
111	76	3.44±.21	3.55±.30	.30±.02	.31±.03	2.77	.08	43	44
113	77	2.81±.16	3.35±.26	.25±.01	.30±.02	2.09	.17	55	33
114	74	2.82±.28	3.44±.30	.33±.03	.40±.03	2.08	.26	44	24
115	75	2.01±.09	2.82±.40	.28±.01	.40±.05	1.00	.20	54	31
116	78	1.35±.14	3.66±.77	.49±.05	1.32±.28	2.32	.07	37	24
101	—	1.12±.17	———	.40±.06	———	2.86	—	88	—
118	—	3.05±.24	———	.16±.01	———	1.88	—	77	—

	1934	1933
Range in number fish on experiment	2,413—7,500	750—1,250
Range in number pounds of trout per cu. ft. water on experiment	1.08— 4.48	.58— 3.26

Table 8 shows the efficiency of fingerling brook trout in the conversion of the various combinations of commercial feedstuffs into live body weight. Each conversion value represents the mean of

a series of two weeks periods since the fingerlings were weighed periodically at those times. As will be noted we had better conversion efficiency in 1934 in all lots. Although a different strain of fish was used it seems doubtful if the difference was due to this fact. The better efficiency probably was due to better technique in conducting the experiments. Close observation of the values for the two years on the various feed combinations show that there is some parallelism in the relative differences. It shows that we were able to duplicate our first year's results quite closely using another strain of trout. The fish fed Diets 101 and 118 were held in our production hatchery where the water has a higher temperature during the summer, the temperature there varied from 50° to 59° F. They may be compared to 116 and 110 respectively, held in the experimental hatchery with the cold water. As the data indicate, the warmer water gives a better feed conversion. The same relation between the liver and dry feed-liver groups is maintained, however, the latter being the more economical in both cases.

Likewise, it will be noticed that there was a better growth the second year. In both years the group fed the liver diet was one of those making the poorest growth. Those making the better gains during the two years were Diets Nos. 113, 111, 115, 110 in about that order. Due to the warmer water in our production hatchery both of the groups, Diets Nos. 101, 118 made a better growth as well as a more efficient conversion.

The consistency of a dry feed-meat diet is very important from the standpoint of its efficiency. If the diet is fed too wet there is a considerable waste of food in the water which the fish are unable to use; if the diet is fed too dry there is also a waste as the fish are unable to break up the food and it will remain on the bottom of the troughs uneaten. In making up our dry feed-meat diets we mix up a supply of the components of the dry feed in suitable quantities, fifty pounds or more. This is our "stock mixture." At the time the diets are prepared for feeding we have two materials to put into the diet—the "stock mixture" and the meat. Let us assume that we wish to make up one kilo of Diet 110. First we weigh 150 grams (15% of diet) of raw liver, then we weigh 850 grams of our "stock mixture" (85% of diet—one-third each Spray Process skim milk, cottonseed meal and fish meal). Then we add 850 grams (85% of the diet) of water and thoroughly mix the diet. This is allowed to set for several hours; it is better to allow it to set over night if possible, in order that the dry feed will absorb all of the meat juice and water possible. The diet is then ready for feeding. We prepare all diets every other day in order that we may economize on time. The amount of diet to feed for the two-day period is calculated from the total weight of the fish obtained periodically.

Technique in Conducting Feeding Experiments

Weighing Experimental Groups of Fish

Last year we started weighing the fish on our fry-fingerling experiments at intervals of two weeks. Previously we had weighed all our fish at four week intervals. This change was made for two reasons. Small fingerlings on some diets will double their weight in four weeks at our water temperature. Assuming that they were being carried at the start at average capacity of the troughs then at the end of four weeks an over-crowded condition would exist, limiting growth and increasing potential or actual mortality. If at the start only a few fish are placed in a trough, in order to prevent overcrowding four weeks hence, then the amount of food allowed them will be so small with such a relatively large space in which to feed it, that there is apt to be wastage and a high food coefficient.

The second reason for weighing our fish at two week intervals is that we allow them food in proportion to their body weight. If we allow them 10% of their body weight of food during a four week period, based on their weight at the start, and they double their weight during this period, then at the end they would be receiving only 5% of their body weight. Although we could calculate new amounts to feed every week from the current gains the fish were making, we consider this too inaccurate to use for four-week periods.

Since yearling and adult trout do not grow as rapidly as fingerlings, we continue to weigh these at four week intervals.

All fish on each experiment are included in the weighing. If samples of fish are taken from the different groups there is always the possibility that they are not the average members, and if such were the case, they would invalidate the data.

Weight of Trout per Cubic Foot of Water

Unless fish on different experimental groups are carried at approximately the same weight per cubic foot of water, the resulting data from such experiments may be meaningless. The growth of fish that are crowded is restricted (Davis, 1934). Fish not crowded would have the advantage in growth. If experiments are carried on using small numbers of fish, so small that there is no possibility of overcrowding, then there is apt to be food wastage and inefficient conversion. In some types of experiments, where it is expected there will be a high mortality, or where it seems inadvisable for other reasons to carry troughs at usual capacities, small weights per cubic foot of water are carried, but unless care is used conversion data may not present the true picture. In practical experiments we try to carry our trout in troughs, as follows:

Size of Trout	*Weight of Trout per Cubic Foot Water*
1 inch	1.0 pound
2 inches	1.5 pounds
3 inches	2.5 pounds
4 inches	3.25 pounds
5 inches	3.75 pounds
6 inches	4.0 pounds

These values are taken in part from the data presented by Deuel (1934) and from unpublished data obtained from him later.

Each time we make a weighing of our fingerlings, we reduce the number of fish in the troughs to a weight equal that of the poorest group. Then all groups in the experiment start the new two-week period at the same weight per cubic foot of water. When an over-crowded condition exists the number is further reduced in order that this new weight at the start each time will conform to the above table for the various sizes.

Calculating Amounts to Feed Trout

For a number of years we fed our experimental groups in the same manner as followed in most production hatcheries. At each feeding the fish were fed amounts that appeared fully eaten. With some diets there is undue waste due to poor physical consistency and fish are unable to eat all that they are allowed. Due to this fact, as well as our desire to improve our technique in general, we started allowing all fish, of approximately the same size, food in daily amounts equal to a certain per cent of their body weight. Then if a group of fish made poor growth, due to a diet having poor consistency or for other reasons the factor of food allowance was not limiting in comparing such a group with others.

At each periodic weighing we calculate how much to feed our fish for the following week. Then we obtain a theoretical weight of fish on hand at that time by using the weight at the start of the two weeks period and multiplying it by the current weekly gain in per cent and adding the product to the weight at the start. From this new theoretical weight of fish at the middle of the two week period, we calculate how much to feed our fish for the last week of the period. The amounts of food to feed are calculated for two days, prepared every two days and kept in ice chests. Since we usually have about forty different diets to prepare, it seemed impractical to make these up each day due to labor shortage as well as the fact that they keep in good condition in the ice chests for that time. As the mean weight of the fish increase, we decrease the amount of food fed in per cent of the body weight. At our water temperature we can start fry feeding with an amount of food daily equal to 10% of their body weight and gradually decrease this so that when their

average weight is five grams (ninety-one trout per pound), they receive food equal to 5% of their body weight. At present we have experiments in progress to determine the most economical amount to feed trout of various sizes in 47° F. water and these results will probably change the above figures.

We feel that the question of feeding experimental groups of fish the same amount in per cent of their body weight is very important. A 1% difference in the amount fed not only means a different food intake but the factor of growth also enters and both are reflected in data showing food conversion. Many nutriton experiments may be criticized for this lack of technique.

Treatment and Prevention of Disease

In order that the occurrence of fish parasites should complicate our experiments as little as possible we have treated our trout at weekly intervals according to methods described by Kingsbury and Embody (1932) and Davis (1934). We usually give the fingerlings a 2.5 salt bath at one to two-week intervals. We are especially interested in having our experiments that continue for a long period undisturbed by disease that are not of nutritional origin, since such studies increase materially in value as the period lengthens.

Annual reports of the experimental work at this hatchery are published by New York State Conservation Department, Albany, New York. Details of the experiments presented in this paper as well as other experiments may be found in these annual reports (McCay, 1932), (McCay and Tunison, 1933, 1934).

In conclusion we wish to thank Dr. L. A. Maynard for assistance and advice during the course of these experiments. We are indebted to Dr. Mary F. Crowell for assistance given us in the analytical work connected with the fat studies.

Summary

Data are presented to show that brook trout absorb calcium from the water in which they swim as well as from their diet.

Methods of conducting digestion trials with brook trout are described. The utilization of three different fats, salmon oil, cottonseed oil, and hydrogenated cottonseed oil by brook trout has been determined by measuring accurately the weight of fat ingested and that excreted. Data from sixteen such trials indicate that trout digest cottonseed oil and salmon oil equally well. Even when the diet includes more than 25% of those oils they are used to the extent of 80% to 90%.

Hydrogenated cottonseed oil (Crisco) which melts at 43° C. (110° F.) is not digested as efficiently as the oils that remain in the liquid state at 8° C. (47° F.), the temperatures at which these trials were run. Considerable amounts of even this high melting fat are digested, however.

These fats seem to be used by the body to the same extent whether they are fed at low or high levels. Small trout weighing two grams digest and

utilize these fats to the same extent as the large ones weighing a hundred grams.

Growth curves of four trout species,—lake, brown, rainbow and brook, and data showing the efficiency of food conversion of each of the species are presented. After the thirty-second week the growth rates for the different species are nearly parallel. The lake trout are the most economical and the brown trout the least in regards to their conversion of food into body tissue.

Data from dry feed-meat mixtures of skim milk, cottonseed meal, white fish meal, salmon egg meal and raw beef liver show the economy of inclusion of such dry foods in the trout diet. The data from these tests of the same diets, using a different strain of brook trout, conducted a second year show that the relative difference of six diets was approximately duplicated.

A discussion is given on the technique of conducting nutritional experiments with trout.

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SURVEY OF FISH HATCHERY FOODS AND FEEDING PRACTICES

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At the third meeting of the National Planning Council of Commercial and Game Fish Commissioners, at Chicago, on April 10, 1935, the rising costs of packing-house products for fish food were brought forcibly to the attention of the State and Federal fish hatchery operators. At the time of this meeting the prices of packing-house products were nearly double what they were at the same time in the previous year. Because of this, some hatchery operators feared their present funds for fish food would not purchase the amount necessary to maintain the large stocks of brood and young fish held at their establishments. Therefore, the meeting devoted considerable attention toward this problem.

During the meeting consultations were held with representatives of the meat packers toward determining if economies might be effected in the sale and handling of packing-house products used by the hatcheries, but these did not result in definite conclusions.

Following these consultations various members of the Council discussed on the floor of the meeting their experiments with the feeding of other foods than meat products. Inasmuch as it was apparent from these discussions that other foods offered a solution to the problem of rising hatchery costs, the Council felt it was worthy of more extensive study than could be given at that time. Therefore, a National survey of all hatchery foods was recommended.

Commissioner Frank T. Bell volunteered the services of the Bureau of Fisheries to conduct the survey, and following is a resume of the data obtained in this work by the writers.

Neither of the writers professes to be a fish-culturist, either in a practical or theoretical sense; rather, we have attempted to view the fish food situation from a detached viewpoint, and have recorded our observations from the data obtained in correlation with the experience of other investigators in this field. Our study deals purely with the economic aspects of the problem—we have conducted no feeding experiments. However, we feel that the results of our inquiry may be of interest in bringing to your attention various facts which may aid in the selection of fish foods based on the experience of practical fish culturists and research workers.

In beginning the study it was believed that it should be conducted so as to develop information along two general lines—(1) to learn how economies might be effected in the sale and handling of packing-

Acknowledgment: The authors gratefuly acknowledge the assistance given by the various State Fishery Agencies, private hatchery operators, producers of fish foods, and the several state members of the Bureau's staff who aided in the preparation of this paper.

house products marketed to hatchery operators, and (2) to learn the kind and volume of fish foods used, sources of supply, costs of these foods, and an indication as to the relative standing of these foods in the diet of hatchery fish.

To do this questionnaires were sent to all the Federal, State, and private hatchery operators known to be in business, and personal visits were made to the officers of various meat-packing establishments in Chicago, Illinois, and Kansas City, Missouri. Questionnaires also were sent to producers of fish foods. Very gratifying results were obtained from the questionnaires, reports being received from all the hatcheries of the U. S. Bureau of Fisheries and from all of the State hatcheries except for those in six States. It is estimated that the reports from the State hatcheries represent about 85 per cent of the total business done. About two-thirds of the private hatchery operators responded, but we have reason to believe these included most, if not all, of the larger ones. In fact, we believe many of those not responding are out of business. We feel that our returns cover about 85 per cent of the fish hatchery business done in the United States. In all, replies were received from the activities of about 676 hatcheries and rearing stations. Very complete reports also were received from producers of fish foods.

The hatcheries and stations replying to the questionnaires propagated mainly Salmonidae (salmon, trouts, and whitefishes), Centrarchidae (crappie, largemouth black bass, smallmouth black bass, rock bass, and other sunfishes), Siluridae (catfishes), Percidae (pike and yellow perches), and Serrindae (white bass).

Foods Used

According to the data obtained, the hatcheries and rearing stations upon which reports were received consumed 11,455,000 pounds of foods, valued at $608,000 during the year 1934. This consisted of four general groups of products, namely, meat, 8,554,000 pounds; fishery, 2,092,000 pounds; dairy, 184,000 pounds; and plant products, 625,000 pounds.

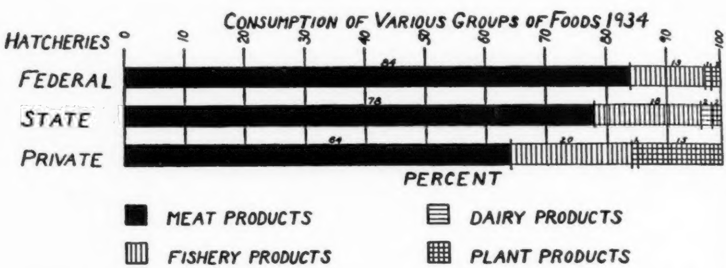
Table No. 1 and Chart I show the comparative consumption of the various groups of food in the different types of hatcheries. From these it will be noted that Federal hatcheries place great dependence upon raw packing house products, State hatcheries lesser dependence, and private hatcheries least dependence. Conversely, the diet of fish raised in private hatcheries consists to a large extent (36 per cent) of fishery, dairy, and plant products.

In this connection it is noted that the commercial culturist employed 41 kinds of products as fish foods in addition to the standard fresh packing house products, during 1934, whereas Federal hatcheries supplemented 30 products to the list of fresh meat diets. It appears that private hatchery operators are influenced to a great extent in their choice of fish foods by the factors of price alone since they consumed

TABLE 1. COMPARTIVE CONSUMPTION OF VARIOUS GROUPS OF FOODS IN THE DIFFERENT TYPES OF ESTABLISHMENTS

	Type of Hatchery							
	Federal		State		Private		Grand total	% of grand total
Type of product	Pounds	% of total	Pounds	% of total	Pounds	% of total	Pounds	
Meat	576,469	84	5,844,654	78	2,133,344	64	8,554,467	75
Fishery	92,776	13	1,309,331	18	689,711	20	2,091,818	18
Dairy	4,629	1	141,843	2	37,125	1	183,597	2
Plant	14,097	2	113,980	2	496,976	15	625,053	5
Total	687,971	100	7,409,808	100	3,357,156	100	11,454,935	100

CHART NO. I



80 per cent of the low-priced plant products and 33 per cent of fishery products used in hatchery feeding operations in this country. In 1928, James (a) found approximately the same situation existing. This seems to show that low-priced foods have favorable nutritive qualities in the diet of artificially propagated fish.

Cost of Foods Used

That the hatchery operators apparently have cause for complaint on the increasing cost of fish foods in 1935 is indicated in Table 2 and Chart No. II, which show that the average costs of all types of meat products increased 39 per cent over the cost of these products in 1934; dairy products, 20 per cent; plant products, 11 per cent; and fishery products, 4 per cent. To some it may seem that the price for meat products is rather low, for during recent months we have heard of prices of beef liver ranging from 12 cents to 16 cents per pound or higher. However, it should be remembered that these are average prices for all meat packing-house products. More detailed prices for the individual items are given later in the report.

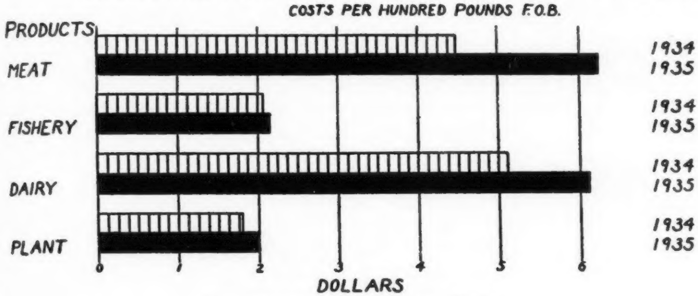
TABLE 2. COMPARATIVE COSTS OF THE VARIOUS GROUPS OF FOOD USED AT HATCHERY ESTABLISHMENTS 1934 AND 1935

Product	Cost per 100 pounds f. o. b. 1934	1935	% of increase over 1934
Meat	$4.49	$6.25	39
Fishery	2.06	2.15	4
Dairy	5.10	6.12	20
Plant	1.80	2.00	11

CHART NO. II

COMPARATIVE COSTS OF VARIOUS GROUPS OF FOODS 1934 AND 1935.

COSTS PER HUNDRED POUNDS F.O.B.



Description of Food Used

Meat Products

The various meat products used as food in fish hatcheries are, as is well known, derived from cows, sheep, hogs, and horses. We also found one operator in the Middle West who reported he used meat from jack rabbits and other local animals for fish food. Some fresh blood from cattle and ducks, which probably was mixed with animal meals or cereals, has been used in feeding fish. The more common products consist of the raw meat of the animal and such packing-house products as livers, hearts, kidneys, lungs, and the like. In general practice these are delivered to the hatcheries in the fresh condition although considerable quantities are received frozen. Frozen stocks are sometimes packed during the peak of the slaughtering period and held in cold storage pending distribution. Meat products also may be dehydrated and marketed as dried and ground meals.

Meat products are also used in preparing various kinds of canned fish foods. In these instances the meat product is mixed with cereals or other food substances to form a more or less balanced ration. The price of all types of fresh meat and packing-house products averaged $6.25 per hundred pounds, f.o.b. packing plant, during 1935. As a rule, the Federal and State hatcheries make greatest use of the meat products.

Livers.—Livers as obtained from cattle, sheep, hogs, and horses are in demand especially as a food for very young fish and fingerlings. Average price: from cattle, $9.48; sheep, $6.77; hogs, $6.89; and horses, $9.00.*

Kidneys.—The raw kidneys as obtained from cattle and hogs also fill a large place in hatchery feeding practices, especially for feeding

*The average prices shown for the various individual products are the f. o. b. prices during the summer of 1935 in 100-pound lots at the slaughter house as reported by the various hatchery operators. The average is computed by taking the price as listed on all reports from hatchery operators, adding them together, and dividing by the number of reports.

fingerlings. Average price: from cattle, $4.50 (delivered 1934), and hogs, $4.00.

Hearts.—Beef, sheep, and pork hearts are among the most sought after products for hatchery feeding, especially for fingerlings. Average price: from cattle, $10.08; sheep, $9.00 (delivered), and hogs, $5.00.

Lungs.—Lungs are usually obtained from cattle, but in some instances private hatchery operators use lungs from hogs which undoubtedly have passed Federal inspection, or they may have been obtained from a local slaughter house not under Federal inspection. Lungs are used mainly for feeding adult fish. Average price: from cattle, $3.43 and from hogs, $2.50 (delivered).

Melts.—These are the spleen of cattle and hogs. Average price: from cattle, $4.90 and from hogs, $4.28 (delivered). Melts are desired by hatchery operators for feeding adult fish.

Plucks.—These are the hearts, livers, and lungs of hogs and sheep incorporated in one unit or mass. They are used mainly for feeding adult fish. Average price: from hogs, $2.00 and from sheep, $6.80.

Meat meals.—These are made by dehydrating various meats and meat products and consist of such items as whole beef, beef blood, and livers. Tankage is a dry product obtained from the offal collected at the slaughter houses. These products seem to find favor in feeding fingerlings as well as adult fish. They are undoubtedly used in combination with fresh meat products as in process of manufacture some of the nutritional value of the original product may be lost. Average price: beef meal, $3.50 (delivered); blood meal, $2.55; meat meal, $4.88; dried meat, $6.50; tankage, $2.42 (delivered); and liver meal, $15 (delivered).

Fishery Products

The fishery products used for fish foods in the various hatcheries canvassed consisted of whole, fresh, and frozen fish, fish trimmings, canned fish, fish and shellfish meals, and fish oils. These products are important in the diet of fish in the country's hatcheries, over two million pounds being used in 1934. In general, the State and private hatcheries are the largest users of these types of foods. In fact, the private hatcheries place great dependence upon these foods as a diet for growing fish. This, no doubt, is due to the fact that in the private hatcheries the fish are raised to a much larger size than in the average State or Federal hatchery. This of course involves a much longer feeding period and food costs, therefore, are of greater significance. During 1935 fresh fishery products cost the hatchery operators on an average of $2.15 per hundred pounds, f.o.b. production point, which is about one-third the cost of fresh meat products.

Fishery products are usually fed in combination with fresh meat products and apparently as a substitute for a straight meat diet. It is believed, however, that when the advantages of fish are known for feeding hatchery fish, the use of these products will greatly increase. In

fact, it may form the larger part of the diet, the fresh meats being fed in combination with it only to the extent absolutely necessary. In this connection it is interesting to note the results of the study by Juday (1908) (b) of the stomach contents of various fishes taken in the Twin Lakes of Colorado. The only mammal remains he found were taken from the stomach of a rainbow trout and this amounted to only .04 per cent of the total stomach contents of all the rainbow trout examined. On the other hand, he found that 26.55 per cent of the stomach contents of all the rainbow trout examined contained fish remains and 8.70 per cent vegetable remains. This quantity was exceeded only by the amount of insect fragments, which amounted to 31.70 per cent, and were found in the stomachs of the rainbow trout examined. In the case of large brook trout examined he found the fish remains amounting to only 1.48 per cent, insect fragments 31.10 per cent, and vegetable debris 36.05 per cent. It is interesting to note from Juday's findings that natural foods of rainbow and brook trout are closely correlated with the results of trout feeding experiments conducted by Davis and Lord (1930) (c). Davis and Lord found that a complete fish diet was unsuitable as a food for brook trout fingerlings since it was always accompanied by high mortality and inferior growth. The rainbow trout fingerlings, however, did fairly well on a straight fish diet, making a good growth accompanied by a moderate mortality.

Alewives.—Quantities of alewives are used by various hatchery operators especially along the Atlantic Seaboard. These fish are taken in the coastal streams along the Atlantic Coast, chiefly in Maine, Maryland, Virginia, and North Carolina. They are used mainly for salting. The runs occur during the spring months of the year in the South and in the early summer in Maine. In hatchery operations the whole fresh or frozen fish is used, being ground and mixed with meat or plant products. During the run alewives may be purchased at a low price. At this time of the year they might be frozen and held in cold storage at convenient points pending use. Alewives are available from various fishery firms in the States where taken. Average price, $1.00.*

Carp.—The use of carp as a fish food has found favor with many hatchery operators for feeding trout from the fingerling size upward and for pond fishes. Fresh, frozen, and canned carp are used as well as carp meal. Fresh carp is used to a large extent by hatchery operators in the Mid-West and to some extent in the Pacific Coast States. In Ohio the State hatchery officials maintain seining crews to remove carp from State-owned reservoirs. The carp taken are ground and used as bass food. It is estimated that carp taken in this manner costs about three-quarters of a cent per pound. During 1934, 100 tons of carp were taken in this manner by the State seining crews.

It is possible that carp may be taken in many other lakes in the

*The average prices shown for the various fishery products are the f. o. b. prices during the summer of 1935 in 100-pound lots at the point of production, as reported by the various hatchery operators. The average is computed by taking the prices as listed on all reports, adding them together, and dividing by the number of reports.

country and used for fish food, especially from those lakes where the State believes the carp is a nuisance and is harmful to other fish. If the quantity taken at any one time is too large to consume in the fresh condition, it might be frozen, canned, or converted into meal. In this connection Wm. H. Dumont, an agent of the U. S. Bureau of Fisheries, reports that the State of Wisconsin, during the latter part of May, 1935, contracted to have carp seined from a lake near Madison. One single haul resulted in the capture of about one million pounds of carp. These were impounded in ponds for later sale as human food.

In Oregon one commercial hatchery operator retains live carp in ponds on his premises where they are available when needed for fish food. He reports good results in feeding trout on the carp after it has been cooked.

The State hatchery officials in Colorado report they have had splendid success in obtaining growth in trout by feeding them canned carp in combination with a canned meat product. The fish fed are retained in ponds where some natural foods are available. Very little raw liver is used except for baby fish. Canned carp is available from a canning firm in Denver, Colorado.

Several of the State and Federal hatcheries in the Rocky Mountain area use carp meal in combination with raw meat products for feeding trout from the fingerling size upward. Carp meal is available from a reduction establishment in Murray, Utah. The U. S. Bureau of Fisheries ratcheries at Leadville, Colo., Bozeman, Mont., and Saratoga, Wyo., report especially good results with carp meal as a feed for trout.

The canned carp and carp meal may be especially valuable as a fish food as the bones are entirely edible, thereby providing a source of minerals to the fish. The average cost of fresh carp is $1.00; canned carp, $5.50; and carp meal, $5.50.

Sea herring.—Considerable quantities of fresh and frozen sea herring are used by private and State hatchery operators for feeding trout. In practice the whole fish is ground and fed in combination with fresh meat products. Sea herring are available along the North Atlantic Coast and off Washington and Alaska. In 1933 over 190,000,000 pounds were taken. On the Atlantic Coast the season extends from April to about September, off Washington during the early spring months, and off Alaska from June to October. Most of the catch is used for salting, smoking, and canning. Large quantities of the waste from these operations are converted into meal. The average cost for the fresh and frozen sea herring used by hatchery operators was $1.94. Supplies of fresh and frozen herring are available from various fishery firms in the areas mentioned above.

Several private hatchery operators rearing trout in Massachusetts have advised that good results were obtained with the use of sea herring in combination with fresh packing-house products. Many of these operators place sea herring at the head of the list as a substitute for a raw meat product. Hatcheries located near the Atlantic Coast might

make more extended use of sea herring, especially in combination with raw meat products. Supplies could be frozen during the season and held in cold storage at strategic points pending use.

Mackerel.—Fresh, frozen, and canned mackerel is used as a food at various private hatcheries reported. The fresh and frozen mackerel is used mainly in New England. Fresh mackerel are available from fish dealers along the North Atlantic Coast from April to November and frozen mackerel is available all the year round. In California the season extends from June through December. In this State they are used mainly for canning. One firm at Wilmington, California, cans mackerel in combination with cereals for use as an animal food. This has been used as a fish food at various hatcheries.

The average cost of fresh and frozen mackerel to hatchery operators in 1935 was $1.25 and the canned product $5.50.

During 1933 about 111,000,000 pounds of mackerel were landed in the United States, the bulk being handled by fishery firms in Massachusetts and California.

Salmon.—Considerable quantities of salmon products are used by all types of hatchery operators. Probably no other fishery product has such universal use. Products of the salmon consist of the flesh—fresh, frozen, salted, and canned; salmon waste—fresh, frozen, and in the form of meal and oil; and salmon eggs—fresh or frozen or as meal. Extensive use is made of all types of salmon products by hatcheries on the Pacific Coast. The U. S. Bureau of Fisheries is experimenting with manufacture of meal from spent salmon to feed fish.

Much of the flesh is derived from spent salmon obtained in egg-collecting operations and some directly from the spawning grounds. These fish may be frozen, salted, or canned. Some canned salmon is obtained as rejects in commercial cannery operations. Some waste and cuttings accumulated in various salmon canneries in Washington and Oregon is collected and frozen by State operators. Other quantities are reduced to meal and oil by cannery operators. Some surplus salmon eggs are reduced to meal and in this form have found a wide use as trout and fry food in nearly every section of the country where Federal, State, and commercial hatcheries are operated. This product has been especially valuable in giving the trout a natural color and gamy appearance. Nearly all operators report good results by using this meal in combination with fresh meat products of rearing fingerling and larger salmonoids. Fresh and frozen salmon eggs are also utilized to some extent in hatchery feeding operations in Washington and Oregon. These eggs are sometimes cooked until they separate and turn white upon immersion in cold water before being fed to the fish. In this manner they do not grease the water as they would when fed to the fish in the raw state. These eggs, due to their size, are most suitable for feeding to the larger trout and salmon.

The salmon products are available from various fishery firms in Washington and Oregon. Average cost: spent salmon, $1.75; canned

salmon (rejects), $3.50; fresh or frozen salmon, offal, $0.88; salmon meal, $4.17; salmon egg meal, $7.08 and salmon eggs, $2.50.

Miscellaneous fish.—Quantities of chubs, minnows, pickerel, pilchards, shad, squeteagues, suckers, and some minor quantities of marine fishes have been used by the hatchery operators. These are utilized principally at hatcheries near points of production. In addition, some use is made of white fish meal (cod, haddock, etc.) and menhaden meal. Some experiments have been conducted with pilchard meal in California.

In general, reports indicate that these fishery products are valuable for feeding trout and pond fish under certain conditions, especially when combined with raw packing-house products. Most of the above products were used by private hatchery operators.

In addition to the above, there are many other species of fish and fish waste which might be used for hatchery feeding. At times during the runs of these fishes stocks might be obtained at an economical price, then frozen and held in cold storage pending use.

Experiments have been made in feeding artificially propagated goldfish, unsuitable for aquarium use because of color, as forage fish for pond fishes. Results have not been particularly encouraging due to the carp-like habits of the goldfish.

At such ports as Boston and Gloucester, Mass., Portland, Me., New York, N. Y., Seattle, Wash., San Pedro, Calif., and others, large quantities of fish waste accumulate. This material also might be useful as a feed supplement in the diet of fish. To a large extent it consists of the entrails of the fish.

Davis and Lord (1930) (c) reported that menhaden meal and whitefish meal gave quite satisfactory results with yearling trout when fed together in combination with fresh beef liver.

Shrimp.—Shrimp are used for fish foods in the dried state, canned, and ground as meal or bran. Dried shrimp are usually obtained from sundried shrimp spoiled by rains and unfit for human consumption. Shrimp meal or bran is a waste product of the shrimp canneries and large quantities are produced annually, although at the present time only a small percentage of the available supply is being utilized as a fish food. During 1934 the production of shrimp meal in this country amounted to nearly 2,000,000 pounds, most of which was produced in the Gulf States at the shrimp canneries. During the summer of 1935, hatchery operators obtained shrimp meal for $3.00 per hundred pounds, f.o.b. point of production.

It is interesting to note that the only use made of shrimp meal in hatchery feeding was by the Oregon State hatchery operators, and only a small amount was used by them.

Davis and Lord (1930) (c) state that shrimp meal varies considerably in nutritive value but always contains a high percentage of protein and chitin. The latter is, of course, indigestible but may serve a valuable purpose as "roughage." In this respect shrimp meal is quite

similar to the natural food of the trout. Like most marine products, shrimp meal contains a relatively high percentage of essential minerals and from this standpoint alone should prove a valuable adjunct to fresh meats.

According to Davis and Lord (c), shrimp meal is, however, a less satisfactory food for fingerlings than for larger fish, a mixture of equal parts of beef liver and shrimp meal producing a relatively slow growth. But when fed to yearling trout in combination with fresh meats, shrimp meal has given results comparable to those obtained with fish meals. While the growth is not as rapid as with "clam heads," it is quite satisfactory, nevertheless, and owing to the relatively low price of shrimp meal, it may prove to be more economical than the fish meals. When shrimp meal was fed in combination with clam meal, the growth was good and the mortality low. The fish were always vigorous and possessed excellent coloration.

Shrimp meal is probably available the entire year, with the peak of the production in Louisiana in the fall months. It appears that the use of shrimp meal in combination with fresh meat products could be extended to a considerable degree with an appreciable saving in the feeding costs of yearling trout and larger fish, especially by operators who wish to raise the fish to a larger size.

Clam products.—Only a small quantity of clam meal was reported as used for fish food in 1934 and this by the State officials of Michigan. This meal is a waste product from the clam canneries in Maine and is not available in sufficient quantities to be used very extensively for hatchery feeding. It consists of the "clam head" which is a waste portion of the clams used for canning. Davis and Lord (1930) (c) place clam meal at the head of their list as a choice for a substitute in combination with fresh meat products. They found in an experiment on feeding fingerling brook trout over a 5-month period that a mixture of half clam meal and half beef liver produced the most rapid growth and the mortality was comparatively low. Similar experiments with yearling brook trout revealed that even better results were obtained on a diet of 75 per cent clam meal and 25 per cent pig liver, these fish showing an increase of 285 per cent in weight in the two and a half month period during which these feeding experiments were conducted. Two other diets consisting of 60 per cent clam meal and fresh pig liver and sheep plucks, respectively, produced almost as exceptional results. In these experiments of feeding yearling trout the mortality was negligible. At this writing we have no analysis of clam meal.

While clam meal cannot be obtained in sufficient quantities for extensive use in hatchery feeding, yet it is believed that the results of these experiments definitely indicate the possibilities of utilizing this type of fishery product as an important constituent in hatchery menus, especially for yearling and larger salmonoids. In this connection it is interesting to note that experiments are now being conducted with the meat of sea mussels for fish foods. In composition they much resemble

clams. These mollusks are quite abundant in certain coastal areas and their use in commerce as an edible fishery product is quite restricted. It is possible that their value as a fish food may justify a more extensive mussel fishery.

It should be stated also that considerable quantities of scallop trimmings are wasted annually since no use for this product has prompted its recovery. Here again is a possible source of a fish food fairly rich in protein and minerals, and comparable with clam waste. The cost of recovery of this waste would be negligible and it could readily be reduced to a meal at some strategic point on the North Atlantic Coast. During 1933 there were approximately 4 million pounds of sea scallops landed in the New England and Middle Atlantic States.

Dairy Products

Dairy products as fish foods have not as yet become an important supplement in hatchery feeding. Their use in the fish food diet of this nation during 1934 amounted to only 2 per cent of the total products used. This consisted principally of milk products including buttermilk, dry skim milk, clabbered milk, and fresh milk, listed in the order of their importance. Small quantities of cottage cheese and dried poultry egg yolks also enter into the diversified piscatorial menu, but have been relatively unimportant to date. Average cost of all dairy products, $6.12.

The average individual cost of dairy products to hatchery operators in the summer of 1935 was reported as follows: dry buttermilk, $6.70; dry skim milk, $6.02; clabbered milk, $7.67; cottage cheese, $5.00, and dried egg yolk, $8.50.

Probably the most important use of dairy products is the utilization of dehydrated milk products to form a balanced ration in combination with fresh meat products. McCay (1934) (d) reported good results with the use of a 29 per cent level of dry skim milk in combination with other foods. (See chapter on cottonseed meal.) In previous experiments (1927) he found a mixture of skim milk and beef liver to be superior to beef liver alone in feeding brook trout fingerlings.

Davis and Lord (1930) (c) found dry buttermilk to be slightly superior to skim milk due probably to the greater insolubility of the former. They found dry buttermilk to produce a slightly better growth on fingerling brook trout in a 25 per cent combination with beef liver than the same mixture of skim milk and beef liver. Davis and Lord further state that aside from their food value, milk products appear to have a tonic effect and where they can be obtained at a low cost, their inclusion in the diet is advisable since they found trout to be fond of all milk products, either moist or dry.

The Bureau of Fisheries investigators at the Cortland Station in New York have reported good results by feeding trout on a mixture of equal parts of Spray Process dry skim milk, cottonseed meal, white fish meal, and beef liver.

Plant Products

Juday (1907) (b) also revealed the stomach of some fish he examined contained a large percentage of vegetable debris. In the case of rainbow trout it amounted to 8.70 per cent, land locked salmon 13.05 per cent, small brook trout .34 per cent, large brook trout 36.05 per cent, and greenback trout 4.20 per cent. A portion of the debris consisted of seeds and seedpods of land plants, roots *Potomogeton* leaves, and algae.

In this connection it is interesting to note that considerable plant and vegetable foods were used at the various hatcheries surveyed, especially at the State and private hatcheries. In fact the private hatcheries used 80 per cent of the volume consumed. In general practice the plant or vegetable foods are used in combination with raw meat foods. While some hatchery operators use these foods primarily as a binder for raw meat and absorbent for the juices, it is believed they could be used to a greater extent as a real supplement to the diet. Experiments by various investigators have shown that certain plant products have a definite food value to growing fish, and further these products are available at an economical price. For instance, in 1935 the average price of all plant products used at the hatcheries reporting was $2.00 per 100 pounds f.o.b. production point.

In addition to the other products listed, there were 16 plant products which entered into combination with other hatchery foods reported for the year 1934. The large percentage of plant products used by private hatchery operators throughout the country was due probably to their availability and low cost as compared with meat and dairy products. The largest portion of plant products used were grains or cereals and include the following: Alfalfa, bran, bread, corn, cornmeal, oatmeal, wheat middlings, wheat shorts, low grade flour, red dog flour, and whole wheat flour. Other plant products appearing in hatchery menus include: Pinto beans, soy beans, soy-bean meal, cottonseed meal, and peanut meal.

Davis and Lord (1930) (c) experimented with soy-bean meal and cooked pinto beans in combination with fresh beef liver at a 25 per cent level, in feeding brook and rainbow trout. They found that the addition of soy-bean meal to the meat rations of both species of trout, fingerlings, and yearlings, alike resulted in definitely retarding their rate of growth. This was directly proportional to the amount of soy-bean meal used. The use of 25 per cent of cooked pinto beans in combination with beef liver also resulted in a lower rate of growth and higher mortality than the control diet. In this diet, however, the rainbow trout did much better than they did with soy-bean meal and beef liver.

Cottonseed meal.—Only small quantities of cottonseed meal were reported as used for fish foods in Federal, State, and private hatcheries during 1934. These meals were used in combination with fresh meat products, fishery products, or dairy products. Nearly all operators

using cottonseed meal as an ingredient in hatchery food commented favorably upon its results. It should be stated that cottonseed meal can be obtained readily at a very reasonable cost. Over two million tons of this meal are produced annually in this country. The average cost of this meal to hatchery operators during 1935 was $2.00 per hundred pounds. This meal should be popular for animal feeding not only for its low cost but also for its relatively high protein content which runs around 40 per cent. Its possibilities as a use for fish food have not as yet been recognized by Federal, State, or commercial hatchery operators since only 6,700 pounds of cottonseed meal were reported as used in hatchery operations in the entire country during 1934. If such a meal could be successfully utilized as a fish food, the fish culturist would have an abundant supply of cheap food available throughout the year.

Accordingly, McCay (1934) (d) carried out many experiments testing the value of cottonseed meal as a food for trout. He found that when a mixture of cottonseed meal, dry skim milk, and fish meal was used in equal portions, brook trout failed in about 4 months. However, when a 25 per cent level of preserved spleen was used with cottonseed meal, fish meal, dry skim milk, and a small amount of alfalfa, there was no mortality in a period of twenty weeks feeding to brook trout. This ration also produced a good growth. During his experiments he found that a better supplement for a cottonseed meal diet consisted of a 28 per cent level of cottonseed meal combined with 15 per cent fresh beef liver, 28 per cent salmon-egg meal, and 29 per cent dry skim milk. This mixture fed to 1,250 fingerling brook trout produced excellent growth and low mortality. In this combination the low level of 15 per cent of fresh meat proved adequate. McCay concluded from the results of these experiments with cottonseed meal that it could be successfully used in the diet of young growing trout, provided the fish also received a certain percentage of fresh meat products.

Insect Products

Juday (1907) (b) found a high percentage of the stomach contents of rainbow and large brook trout contained insect fragments, 31.70 per cent and 31.10 per cent respectively. With the greenback trout examined, he found the stomach contents consisted of 23.44 per cent insect fragments, with small brook trout 48.10 per cent, and with fry 73.60 per cent. About the same time as Juday conducted his researches, Atkins (1908) (e) found the larva of flies (blue bottle fly, *Calliphora erythrocephalon* and green flesh fly, *Lucilia caesar*) made an excellent food for young salmonoid fishes.

His experiments revealed that not only was the general average weight of the larva-fed fish 91 per cent higher than those of meat-fed fish, but the best of the 7 lots of meat-fed fish were materially below the poorest of the 6 lots of larva-fed fish. Atkins produced the fly larva at the hatchery by exposing slaughter-house refuse, waste fish, and other refuse to the visits of the flies. When stocked with eggs the ref-

use was placed under shelter in specially constructed boxes. Here the larva assembled themselves when fully grown in masses conveniently handled. These larva were fed to the fish when they were of sufficient size to swallow the larva. This was about one month after the fish had begun to feed. The cost of the larva was mainly from the labor involved, although there was some cost for the material needed on which to incubate the larva. Considering all expenses, Atkins found the cost to be 10.3 cents per pound.

The production of the larva, of course, was accompanied with objectionable odors from the decaying flesh. This fact probably has precluded its more general adaptation to commercial practice. However, at the U. S. Bureau of Fisheries station at Fairport, Iowa, the foreman is raising maggots on decayed cattle offal and feeding these to young bass in the ponds at the station with considerable success.

Simms (1908) (f), an English scientist, emphasized the use of worms in the diet of trout. In a report, he urged the use of a gregarious worm (*Tubifex revulorum*) as a food for feeding trout fry from the time the yolk sac is absorbed until they are ready for the rearing ponds. These worms are not found in this country, as far as known, but possibly other related species of Tubifex occurring here may be of value.

While present commercial fish cultural practice may prevent the incubation of fly larva, it appears that it may be possible to make practical use of certain insect products now available. In this connection it is interesting to note that some use has been made of dried silk worms for feeding trout. These are the dried silk worms as obtained from Japan or other silk-producing countries. Only one hatchery reported use of this product which was obtained at a delivered cost of $9.00 per 100 pounds in 1934. It is possible that this product has promise as a food for hatchery fishes. If the criteria of Juday and Atkins are of consequence, then the dried silk worm should result in good growth in hatchery trout. At present, the price is rather high. However, it is believed that with its more general use the price can be reduced considerably. At the present writing, we were unable to obtain an analysis of dried silk worms.

In line with the use of insect products for feeding hatchery fish, reports indicate that the State hatchery at Libson, N. D., is feeding blue gill sunfish on house flies and grasshoppers caught in screen traps. Also, at the Indianapolis State hatchery the operators are using kerosene flares at night over the bass ponds to attract insects. As these drop to, or fly near, the surface of the water, they are caught by the fish. According to the reports submitted by this hatchery, this practice has resulted in an excellent production of bass at this station and it is understood the plan will be adopted at other State stations.

Natural Foods

Commercial hatchery operators have also discovered to a consider-

able extent the value of feeding fish on natural foods wherever possible. During 1934, 120 private hatchery operators reported that they used natural foods alone as a diet for their pond fish and larger salmonoids at least during the summer months. In this manner, it has been possible to produce fish in captivity which more nearly resemble those in their native environment, and this after all is one ultimate goal of the fish culturist.

Several methods of obtaining natural foods have been brought out as a result of this survey. The simplest and most commonly used method consists of rearing the fish in small lakes or small bodies of water having access to streams. Lakes are selected for an abundance of aquatic plant and animal life, including algae, diatoms, small crustacea, insect larvae, minnows, terrestrial insects, etc., which are the natural foods of fish. One operator in Wisconsin reported that he obtained an abundance of natural food for trout by lowering the water in his lake 2 feet for a time and then restoring it to normal level and thereby trapping the terrestrial insects in this area.

The State Fish Commission of Arkansas has developed a very efficient method for solving the problem of increasing costs of fish foods. Briefly, the method used in obtaining food for bass in 1934 was as follows: Forage fish were produced in a pond fertilized weekly with 15 pounds of 41 per cent cottonseed meal and 5 pounds of 18 per cent superphosphate. The pond was stocked with 100 pair adult golden shiner minnows in January, 1934. The fertilizer was added weekly from May 1 to September 1. When the pond was drained in March, 1935, there were 89,250 minnows recovered, a total weight of 595 pounds and averaging 2 to 3 inches in length. These forage fish were produced at a total cost of about $4.70 or less than 1 cent a pound for live forage fish. This production of forage fish proved to be an adequate food supply for the bass in the State ponds of Arkansas during the entire summer. In this connection the State of Arkansas reports that no money has been expended directly for commercial fish foods since 1930.

The propagation of forage fish, of course, is a common practice in pond fish culture. However, if the above methods could be applied by some of the culturists progagating salmonoids in the warmer sections of the country, it would appear that herein lies an effective method of combating the high cost of artificial foods. In general, it is believed that the use of natural foods in the diet of artificially propagated fish could be further extended in areas favored by suitable conditions, especially during the summer months.

Warehousing of Fish Food Stocks

The reports received from the various hatchery operators revealed that on June 1, 1935, they were holding only 533,000 pounds of surplus fish foods. Salmon offal, beef liver, other livers, and canned mackerel accounted for 76 per cent of the total. Three commercial operators and one State hatchery accounted for 70 per cent of the total fish foods

held. It therefore appears that nearly all of the commercial fish foods purchased are obtained as they are required. This may be due to the fact that the operators do not have sufficient storage space at the hatchery to hold any considerable stocks.

For a long range program it would appear that heavy consumers of fish foods might advantageously construct their own cold-storage facili-

TABLE 3. LOCATION OF FREEZING PLANTS AND COLD STORAGE WAREHOUSES IN THE UNITED STATES AND ALASKA, 1929.*

State and city or town	Freeze Number	Store Number
Maine:		
Port Clyde	1	1
Portland	4	4
Vinalhaven	1	1
Massachusetts:		
Barnstable	1	1
Boston	3	3
Gloucester	3	4
New Bedford	...	1
North Truro	1	1
Provincetown	5	5
Sandwich	1	1
Rhode Island: Providence	...	1
Connecticut: Groton	1	1
New York:		
Albany	1	1
Buffalo	2	3
Brooklyn	...	1
Cape Vincent	1	1
Dunkirk	1	1
Elmira	...	1
New York	4	7
New Jersey:		
Jersey City	...	1
Manasquan	1	1
Monmouth Beach	1	1
Newark	...	2
North Wildwood	1	1
Seaside Heights	1	1
Brant Beach	1	1
Pennsylvania:		
Chambersburg	...	1
Erie	7	8
Philadelphia	2	3
Pittsburgh	...	1
Scranton	1	1
District of Columbia:		
Washington	...	1
Virginia:		
Newport News	1	1
Norfolk	1	2
North Carolina:		
New Bern	1	1
Florida: Jacksonville	2	2
Ohio:		
Ashtabula	1	1
Cincinnati	1	1
Cleveland	1	4
Columbus	...	1
Painesville	1	2
Huron	3	3
Sandusky	5	5
Toledo	1	1
Indiana:		
Indianapolis	...	1
Terre Haute	...	1
Illinois:		
Chicago	2	2
Peoria	...	2
Michigan:		
Bay City	1	2
Charlevoix	1	1
Detroit	2	3
Sault Ste. Marie	1	1
Traverse City	1	1
Wisconsin:		
Ashland	...	1
Green Bay	4	6
Suamico	1	1
Minnesota:		
Duluth	2	2
Minneapolis	1	2
St. Paul	...	1
Maryland: Baltimore	...	2
Iowa: Sioux City	1	2
Missouri:		
Kansas City	2	2
St. Louis	1	2
Nebraska:		
Grand Island	...	1
Omaha	1	2
Colorado: Denver	...	2
Kentucky: Louisville	1	1
Tennessee:		
Memphis	1	1
Nashville	1	1
Mississippi:		
Natchez	1	1
Vicksburg	1	1
Louisiana:		
Alexandria	1	1
New Orleans	1	1
Simmesport	1	1
Oklahoma: Muskogee	1	1
Texas: Galveston	1	1
Washington:		
Altoona	1	1
Everett	1	1
Kalama	1	1
Seattle	5	5
Spokane	1	1
Tacoma	1	1
Oregon:		
Astoria	4	4
Bandon	1	1
Empire	1	1
Marshfield	1	1
Portland	2	2
California:		
Long Beach	1	1
Los Angeles	1	2
Pittsburgh	1	1
Sacramento	...	2
San Francisco	2	2
Alaska:		
Juneau	1	1
Ketchikan	2	2
Sitka	1	1
Total	122	168

*Source—Fishery Industries of the United States, 1929. By R. H. Fiedler. Appendix XIV to Report of Commissioner of Fisheries for the fiscal year 1930. Washington.

ties in order to take advantage of seasonal lower prices on packing-house and fishery products and local supplies of other foods.

As an alternative, various hatchery operators might give consideration to the storage of such products in commercial coldstorage warehouses. We are giving above a list of the cities in which such facilities were available several years ago, especially for holding fishery products. (Table 3). The names of the establishments, no doubt, can be obtained from the Chamber of Commerce of each city. From the list it will be seen that establishments are located at strategic points and can serve practically every locality of the country.

Interviews with Meat Packers

In line with the plan suggested for the conduct of the survey, various meat packers were consulted in Chicago, Ill., and Kansas City, Mo., in an effort to learn where and how economies might be effected in the handling and sale of packing-house products to hatchery operators. In the discussions the following points were considered:

(1) Could a change be made in the type of container used for shipping packing-house products? In reference to this we were informed that the shipping container now in use by the various packing plants is not very expensive and any change in its type to lower the cost would result in little, if any, saving.

(2) Would it be possible for buyers of fish foods to adjust purchases to seasons when large stocks are available? It is believed some saving in costs may be effected along this line. In other words, if purchases are made during the peak of the slaughter of the various animals, the price may be less. Other factors may somewhat affect this price. For instance, beef hearts are generally in better demand in the summer than in the winter. Considerable quantities of this product are used in the summer to make sausage. Conversely, beef livers are in greatest demand in the winter.

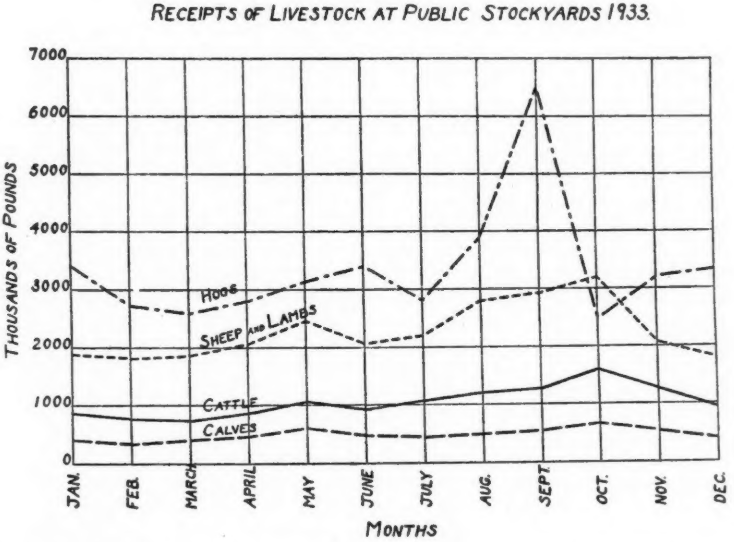
Following is a table (Table 4) showing the receipts of livestock by months during 1933 at about 62 public stockyards. The year 1933 was

TABLE 4. RECEIPTS OF LIVESTOCK AT PUBLIC STOCKYARDS, 1933*

Months	Cattle	Calves	Hogs	Sheep and Lambs	Horses & Mules
January	908,423	416,002	3,387,726	1,914,062	40,246
February	773,146	364,320	2,699,496	1,795,324	35,958
March	758,114	413,265	2,638,341	1,844,202	32,575
April	842,747	453,067	2,797,822	2,096,596	35,668
May	1,030,118	528,291	3,142,938	2,402,427	22,749
June	984,497	464,492	3,361,349	2,091,119	17,698
July	1,008,327	448,133	2,871,352	2,228,071	15,718
August	1,172,730	496,013	†3,923,512	2,794,739	20,731
September	1,178,281	474,313	†6,493,792	2,910,881	34,135
October	1,586,445	591,432	2,521,475	3,268,333	48,632
November	1,202,558	496,268	3,207,163	2,064,263	50,121
December	901,309	441,469	3,331,960	1,774,072	49,413
Total	12,346,695	5,587,065	†40,376,926	27,184,089	403,644

*Source—Livestock, meats, and wool market statistics and related data, 1933. U. S. Department of Agriculture, 1935. Showing slaughter at approximately 62 public stockyards.
†Includes many pigs and sows received for sale on Government account.

CHART NO. III



selected as it is believed this was a more normal year than 1934. This will give some idea as to the months when the production of livers, hearts, etc., of the various animals is at its height.

(3) Would it be wise for fish culturists to pool orders and buy in large quantities? This was discussed with the packers but in general they indicated that this would be an undesirable practice. It was felt that it would result in limited competition as many of the smaller and more localized packing plants would not be able to bid as they would not have sufficient stocks to fill orders. For this reason with fewer bidders the cost might be higher. Also there may be some practical difficulties in developing a plan whereby the various States and the Federal Government could pool orders.

Several of the packers, however, indicated a lower price might result if most of the hatchery operators requested bids at approximately the same time and for a larger volume of product, this to be distributed over a longer period of time. This would create considerable publicity and give the packers a better idea as to the needs of the fish cultural industry so that they would then be in a better position to plan for requirements. In requesting bids it was suggested that they specify an f.o.b. price at a given point. In order to standardize the bids we suggest that a set of specifications be developed by the fish culturists for the

various packing-house products. There might be several grades for a given commodity. By doing this, it is possible that a better product could be obtained at a lower price. Also a grade lower than "first" might be satisfactory and be obtained at a lower price. For instance, we understand that cut beef livers, which have passed Government inspection, can be obtained at a lower price than No. 1 livers.

(4) Are there any bulletins or reports showing the production and holdings of packing-house products? The nearest approach to this are figures on the receipts of livestock at various markets as released by the Department of Agriculture. From these data it may be possible to arrive at approximate figure for the production of beef hearts, beef liver, etc., by computing the proportion each of these components is of the live weight of the animal. This, however, would not be especially reliable as the weights of the livestock slaughtered vary. For all practical purposes, therefore, it is believed a reliable index can be obtained by studying only the figures available currently on the receipts of livestock at the important public stockyards. A compilation for 1933 in this type of business was given previously. Current copies of the reports containing these figures are available from the U. S. Department of Agriculture, Washington, D. C.

(5) Could a saving be effected in the methods of delivering packing-house products to the hatchery? Some of the packers believed substantial savings might be made along this line, while others did not. One suggestion was that the hatchery operators might haul the products from the packing plants to the hatchery by their own conveyance. This would be feasible, of course, where these establishments are fairly near to one another. However, in other cases the costs of the haul might be greater than with regular public conveyance.

Some hatchery operators felt that delivery costs might be lowered by handling only frozen stocks. At present there appears to be little difference between the net cost of fresh and frozen stocks although there is a tendency for the latter to cost less. However, if it is necessary to hold the frozen stocks for any length of time, storage charges may increase the price. If sufficient quantities could be frozen in times of plenty, when raw costs would be low, the resulting product might conceivably cost less, even considering storage charges.

(6) Are there other packing-house products which might be utilized for fish food and which are now being discarded? The packers suggested that greater use might be made of such products as beef lungs, beef melts, beef palates, and cow udders. Some of these products are now used to a limited extent while others may be objectionable because of being too tough or stringy. Consideration might also be given to the use of whale meat for fish food, although it is understood most of this is now used for cat and dog food. Greater use might be made of cut beef livers.

Several other products might be used which have not passed Federal

inspection if treated in an appropriate manner to make them unfit for human consumption. It appears, however, there are certain complications in doing this. If it could be accomplished, hatchery operators might make greater use of hog lungs and sheep livers. In line with the above, it might be possible to use canned shrimp, salmon, meat, and other products which have been condemned by Federal authorities as being unfit for human consumption. Present legal requirements are such that it is extremely difficult to obtain condemned materials and, therefore, this source of supply may offer little promise.

(7) Are the fish culturists of the country meeting with stiff competition in the purchase of certain popular packing-house products, such as beef livers and hearts? With the lower supply and rising costs of meat, consumers have turned more and more to the purchase of various organs of livestock. This has created a brisk demand for beef liver and hearts and other products. New York City alone consumes huge quantities of these foods. In view of this demand, it is doubtful whether the fish culturists can persuade the packers to sell them these products at a lower price than they can obtain for them elsewhere. Of course, this is a temporary situation and possibly will be relieved when an increase develops in the volume of livestock sent to market.

The fish culturist also is meeting competition with manufacturers of cat and dog food in the purchase of packing-house products. This is especially true when prices for these products are lower than at present. At these times the manufacturers of cat and dog food enter the market and purchase large quantities of beef liver, hearts, and lungs. This in turn causes a greater demand for these items and may result in a somewhat higher price level. The canned cat and dog food business of the country is growing by leaps and bounds, and in view of this there is every reason to believe that competition with the manufacturers of these products will increase rather than decrease as time goes on, especially when prices for the various beef products are lower than they are at present. For this reason it may be well for the fish culturist to look to other foods for the fish diet.

Discussion of the Nutritional Requirements of Fish

What are the nutritional requirements of hatchery-reared fish? How much protein do they need? Do they need vitamins, fats, and carbohydrates? Studies have been made to answer these questions, but as yet our knowledge is far from complete. Juday's work (1908) (b) and that of many others have pointed the way, showing us the natural food of trout taken in various waters. However, there is further need to determine the protein, fat, mineral, and other requirements of hatchery-reared fish so that an easily assimilated diet may be prepared and fed which will produce growth with low mortality and result in a fish which resembles as nearly as possible the fish as taken in the wild state.

Extensive work has been done on the nutritional requirements of

many land animals. Detailed studies have revealed the quantity and quality of the various ingredients needed in the diet of cattle, hogs, poultry and other farm animals to produce prime stock at lowest cost. Some work has been done on trout nutrition in this country, especially by McCay and his co-workers (1934) (d). They have considered the food used in rearing hatchery fish from the standpoint of its protein, fat, and mineral content, and the role of these elements in the diet. In one of their experiments an attempt was made to measure the level of protein required by trout. They found that a diet which consisted of about 15 per cent protein, was adequate for the growth of this species of fish, and that any protein level above this should tend to give less efficiency in feed conversion.

Various investigators have studied the use of fats in the diet of trout. McCay (d) reports that the hatchery man can probably work to the best advantage by keeping his diet relatively low in fat until definite advances are made in determining which fats, if any, can be used with good results.

The role of such minerals as calcium and phosphorus in the diet of trout also was studied by McCay (d) and his co-workers. They found that if the water is hard (rich in calcium) there was little need of feeding foods rich in this element as all the calcium needed for the development of the bony and other structures of the fish could be obtained directly from the water. However, if the water used at the hatchery is soft, then it may be necessary to adjust the diet to meet the deficiency.

They also found that the use of yeast, which contains vitamin B, and cod-liver oil, which is high in vitamins A and D, were not justified in the light of present-day experience. It is believed, however, that fish do have a definite need for some vitamins, possibly for vitamin G. Hoagland and his co-workers at the U. S. Department of Agriculture have shown that the livers and hearts of various livestock contain this vitamin. This may account for the necessary inclusion of fresh flesh foods in the diet of hatchery-reared fish as vitamin G is not generally found in dry meat or fish meals. Recent researches, however, may point to the manufacture of a fish meal higher in vitamin G than in the meals manufactured at present.

In various experiments McCay and Dilley (1927) (g) demonstrated that fresh meat is necessary in the diet of fish. It apparently contained some unknown nutritional factor. This they called factor H.

Composition of Foods Used

In light of the foregoing, it is interesting to note the composition of the foods which enter into the menu of the fish reared at various hatcheries and stations during 1934. This information is shown in the following table, which data may give the fish culturist an idea of the relative importance of the various foods, especially from the standpoint of their protein content.

TABLE 5. APPROXIMATE ANALYSES OF CERTAIN PRODUCTS USED FOR FISH FOOD*

Items	Protein Per cent	Fat Per cent	Carbohydrates Per cent	Ash Per cent
Beef: (wet basis)				
Meat	20.0	7.0	----	0.8
Hearts	16.0	20.0	----	1.0
Kidneys	13.7	1.9	0.4	1.0
Livers	20.0	3.0	2.5	1.3
Lungs	16.0	3.0	----	1.0
Melts (spleen)	18.0	2.3	----	1.4
Tripe	16.8	8.5	----	0.5
Horse: (wet basis)				
Meat	20.0	7.0	----	1.0
Livers	20.0	3.0	2.5	1.3
Pork: (wet basis)				
Hearts	17.1	6.3	----	1.0
Kidneys	15.5	4.8	0.7	1.2
Livers	21.3	4.5	1.4	1.4
Lungs	11.9	4.0	----	0.9
Melts (spleen)	17.0	1.9	----	1.4
Sheep: (wet basis)				
Hearts	16.9	12.6	----	0.9
Livers	23.1	9.0	5.0	1.7
Lungs	20.2	2.8	----	1.2
Miscellaneous meat products:				
Blood meal (dried)	82.3	0.9	3.8	3.3
Meat meal (dried)	55.0	12.0	----	25.0
Tankage (dried)	60.0	6.7	----	21.6
Fish: (wet basis)				
Alewives	10.0	2.4	----	0.8
Carp	10.0	0.5	----	0.5
Herring, sea	11.0	3.0	----	1.5
Mackerel	10.0	4.2	----	0.7
Pickerel	9.9	0.2	----	0.6
Shad	9.4	4.8	----	0.7
Spent salmon	Low in oil.	High in protein and ash.		
Canned fish:				
Mackerel	19.6	8.7	----	1.3
Salmon	20.0	7.5	----	2.0
Shrimp	25.0	1.0	0.2	2.6
Fish meals:				
Salmon egg	39.3	8.7	----	10.7
Sardine scrap (pilchard)	62.0	6.0	----	21.0
White fish (meal)	68.0	2.0	----	19.0
Cod-liver	51.0	31.0	----	2.5
Menhaden	61.0	7.0	----	21.0
Shrimp	47.0	3.6	----	30.0
Dairy products:				
Cottage cheese (wet)	16.0	1.3	----	0.5
Fresh milk (wet)	3.5	3.7	4.9	0.7
Dehydrated milk	37.3	1.3	49.3	8.1
Dehydrated buttermilk	34.6	1.9	50.9	8.1
Clabbered milk (wet)	3.3	0.5	3.5	0.6
Dried poultry egg yolk	33.3	51.6	5.7	3.5
Plant products: (dried)				
Alfalfa	14.9	2.3	65.6	8.6
Soy beans	4.1	1.0	16.1	2.4
Soy bean (meal)	43.2	6.6	34.8	4.9
Bran (wheat)	16.0	4.4	63.2	6.3
Stale bread	7.9	0.7	56.1	1.5
Corn	10.1	5.0	72.9	1.5
Corn-meal (gluten)	44.4	2.9	42.0	1.3
Cottonseed meal	38.0	8.0	39.9	6.4
Low-grade flour	13.0	1.7	70.5	0.9
Oatmeal	16.0	6.5	67.6	2.0
Peanut meal	44.8	10.2	33.6	4.8
Red Dog Flour	16.8	4.1	65.6	2.5
Wheat middlings	17.8	5.0	62.8	3.7
Wheat shorts	17.4	4.9	62.8	4.4
Whole wheat flour (graham)	13.7	2.1	70.7	1.5

*Information obtained from Food Analysis, by A. G. Woodman; Food Products, by Dr. H. C. Sherman; Foods and their adulteration, by Dr. H. W. Wiley; Food inspection and analysis, by A. E. Leach; Feeds and feeding, by W. A. Henry and F. B. Morrison; Marine Products of Commerce, by D. K. Tressler; Studies on nutritive value of fish meals, by Esther P. Daniel and E. V. McCollum, U. S. Bureau of Fisheries, Investigational Report No. 2; Unpublished data from U. S. Department of Agriculture, Bureau of Animal Industry, Dairy Industry, Chemistry and Soils, Home Economics, and Food and Drug Administration.

Summary

According to reports received from hatchery operators, they used 11,455,000 pounds of fish food, valued at approximately $608,000, in 1934. Three-fourths of this consisted of meat products. As to the use by the different types of hatcheries, the reports revealed that Federal hatcheries made greatest use of meat products, State hatcheries less use, and private hatcheries least use. As to cost, meat and dairy products were most expensive and fishery products were obtained at about one-third the cost of the former products.

As a result of personal interviews with the meat packers, we see little, if any, immediate hope of any great reduction in the prices of packing-house products, especially for beef liver, hearts, and others of popular nature. True, when the slaughter of livestock returns to normal, the price may be lowered. However, when this time comes, the fish culturist then will meet with competition for these products from manufacturers of cat and dog food. We, therefore, feel that the price level to which these products will fall will still be higher than the fish culturist can pay to conduct economical operations, especially the private operators. Some minor economies may be effected in the method and time of purchase, methods of handling, etc., which may tend to lower the price of these products. The extent of these we are unable to estimate. The shadow of current events leads us to believe the greatest economies will result by the use of foods other than packing-house products. In most instances these other foods are less expensive than the popular packing-house products and many of them have the added advantage of more nearly resembling the foods obtained by trout and other fishes in their natural environment.

It seems to us that if the fish culturist is purchasing fresh meat products mainly for their protein content, he is paying too high a price for this nutritional factor alone. A glance at Table 5 will demonstrate this point. While the average protein content of meat products on a wet basis is approximately twice that of fishery products on the same basis, the cost per unit of the former is about three times that of the latter. In the light of evidence obtained by various investigators, and in the practical operation of governmental and private hatcheries, it appears that the protein content of the ration can be adequately supplied by liberal use of fishery products.

We believe with Agersborg (1934) (h) that one of the natural foods of fish is fish, especially for those fish beyond the fry stage. As to the natural food of fry, many investigators have found it consists to a large extent of insects, small crustacea, protozoa, etc. It is interesting to note that the nearest approach to these diets in actual commercial hatchery practice are those used by private hatchery operators.

From all we can learn as a result of our limited study, and this may be common knowledge of the fish culturist, fry and very young fish need raw meat products in their diet, but as far as we can determine, no one knows why. We have indicated previously that this may be due to the vitamin G content of these foods. However, in view of this uncertainty it may be the part of wisdom to encourage further studies aimed at segregating this factor in raw meats to learn

whether it may not occur in other products available at less cost—thus relieving the fish culturist of the need of purchasing high-priced feed products.

Along this line more extended studies might be made of the role of various other nutritional elements in the diet of trout and the several hatchery fishes toward the end that other foods, such as fishery products, insects, forage fish, plant foods, and the like might be utilized more extensively. Research has revealed the nutritional needs of many domestic animals and it is not inconceivable that the same information could be determined as to the nutritional needs of trout, bass, and other fishes. With the ever increasing demand to stock our waters with fish and the need on the part of governmental agencies to supply these fish at lowest cost, we feel such basic studies might lead to the development of a more economical feeding technique.

FISH FOODS CONSUMED AT STATE HATCHERIES OF IDAHO, NEW MEXICO, AND WASHINGTON, 1934

Item	Quantity Consumed	Average cost per hundred pounds			
		1934		1935	
	Pounds	F.O.B.	Delivered	F.O.B.	Delivered
Fresh meat products:					
Beef—					
Hearts	3,712	$6.25	(1)	$6.75	$9.00
Livers	25,817	6.75	(1)	9.17	10.00
Meat	36,252	(1)	(1)	8.00	(1)
Melts	6,739	4.00	(1)	(1)	6.40
Horse—					
Hearts	250	(1)	2.00	(1)	2.00
Livers	500	(1)	2.00	(1)	2.00
Meat	59,150	(1)	2.50	(1)	2.98
Sheep—					
Hearts	2,000	5.00	(1)	6.00	(1)
Livers	64,458	5.00	(1)	8.75	(1)
Unclassified—					
Livers	110,089	(1)	8.15	(1)	(1)
Melts	15,000	(1)	4.00	(1)	4,00
Fishery products:					
Canned—					
Carp	1,000	4.00	(1)	(1)	(1)
Mackerel (Balto)	2,700	6.00	(1)	6.00	(1)
Spent salmon	287,023	2.00	4.00	2.00	4.00
Other fish	2,500	7.00	(1)	7.00	(1)
Salmon livers	11,043	8.53	(1)	(1)	(1)
Salmon egg meal	1,000	(1)	4.80	(1)	4.80
Dairy products:					
Dehydrated buttermilk	900	3.50	(1)	3.50	(1)
Plant products:					
Whole wheat	1,600	1.60	(1)	1.70	(1)
Total	631,733	-------	-------	-------	-------

(1)—Data not available.

In Washington the spent salmon obtained in spawning operations were canned at various State hatcheries in No. 10 cans weighing 6½ pounds each. Some flour was added to each can to absorb the free oil and make the feed more adaptable. The cost of preparing salmon in this manner was reported to be 2 cents per pound. This feed was used in combination with other products to feed chinook, silver and steelhead fry.

The reports received were for 24 hatcheries.

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(d) McCay, C. M., and co-workers
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(e) Atkins, Charles G.
1908. Foods for young salmonoid fishes. Bulletin of the U. S. Bureau of Fisheries, Volume XXVIII, 1908. Bureau of Fisheries Document No. 684. Washington.

(f) Simms, G. E.
1908. An improvement in hatching and rearing boxes; with notes on the continuous feeding of the fry of salmonidae. Bulletin of the U. S. Bureau of Fisheries, Volume XXVIII, 1908. Bureau of Fisheries Document No. 704. Washington.

(g) McCay, C. M., and Dilley, W. C.
1927. Factor H in the nutrition of trout. Trans. Amer. Fish. Soc. 1927. Hartford.

(h) Agersborg, H. P. K.
1934. An inexpensive balanced diet for trout and salmon. Trans. Amer. Fish. Soc. 1934. Hartford.

Addendum

Since the compilation of the data incorporated in this report, the following additional information has been received from the State officials of Idaho, New Mexico, and Washington:

Discussion

Dr. H. S. Davis (Washington, D. C.): The paper which Mr. Fiedler has read lays a good deal of emphasis on the use of fresh fish as fish food, but experimental work does not bear out the assumption that entirely satisfactory results will necessarily follow from the feeding of large quantities of fresh fish. Where a large quantity of fresh fish is included in the diet for any considerable time we have found the results have not been what we would naturally expect. In some cases I have known of heavy losses which were directly traceable to that cause. Of course in this case they were using cheap fish which perhaps were not any too fresh when they were frozen—the fish were shipped in frozen condition—and when the fish dealers get only a cent and a half or two cents a pound for their product they naturally do not take a good deal of trouble with it. The result is that often when that fish is received it is not in very good condition.

I think some of the most serious mortalities attributable to feeding of fish can be traced to the fact that the product was not as fresh as it should be.

Then there is another point that is of importance in relation to the use of fresh fish in the diet of trout. Many of the hatcheries are inland, where a long shipment is necessary to get the fish to the hatchery. Obviously the hatcheries on the Atlantic or the Pacific seaboard, where shipments would require only a few hours, can get cheap fish which is very often in good condition; but even there I doubt the desirability of too large a quantity of fresh fish in the diet. Personally, as a result of our experience and experiments carried on over a considerable number of years, I am inclined to think the most promising field for reducing the cost of trout foods is the use of dried animal products. We can buy animal meals for anywhere from forty dollars a ton to eight or ten cents a pound; but even there you will find they are much more economical than the cheapest of the fresh meats, because in the case of the fresh meats your cost is multiplied three or four times before the material is ready for use. So that even if you are paying six or eight cents for your dry meal it is much cheaper than the cheapest of the raw meats.

In cases where a considerable percentage of the better meat products is used in the diet I am convinced you can produce better fish much more cheaply than you can on all raw meat diet. We have done it, I know, and other hatcheries do the same thing. One notable case with which you are all familiar is that of Mr. Hayford's hatchery in New Jersey. For several years I had been trying to get him to use dried meat products, but he was in the habit, as most of you are, of using fresh meats. This year, however, finding the cost of meats prohibitive, he has developed a diet composed of sheep pluck, fresh frozen mackerel—which are just as good as any frozen mackerel put on the market for humans—meat meals and whitefish meal and dried buttermilk. He has told me that as a result of that diet he is getting better fish at less cost than he got last year with the regular diet.

Mr. Joseph H. Wales (California): In connection with what Dr. Davis has said, I believe the increase in the price of fresh meat is one of the best things that could possibly have happened so far as progress in the matter of trout feeding is concerned. In California we have been conducting a large number of experiments in trout feeding. Until recently the price of fresh meat has been such that the State of California has been feeding practically all its trout on these fresh meats, but this last year has shown the state it is utterly impossible to continue to use fresh meats, that we have to do something very definite and do it in a hurry in order to bring down the price of our trout. The result is that I have had a great deal more support in my investigations with substitutes than one would naturally expect a scientist to get.

There is another point: I wonder, Mr. Fiedler, whether you have found any states which have large storage plants in which they could put up large quantities of fresh meats at times when the prices are exceptionally low and keep them in storage while the prices are up.

Mr. Fiedler: Yes, that is covered in the paper. I have a list of cold storage plants all over the country where various meat and fishery products may be held. There is a storage plant near enough to nearly every fish producing locality in

the country, and also near enough to every fish hatchery—this will cover Dr. Davis' point—to enable the hatcheries, especially those in the interior points, to order these fish or meat products in carload lots, hold them in cold storage and take them out in their own trucks when needed.

As to the use of dry meals, that also is covered in the paper; I did not have time to read it. Menhaden meal, clam meal and various other products are used extensively where the supply is large enough to justify it, and, as Dr. Davis has said, it would be a good substitute for the fish.

THE PRESIDENT: What about the bass culturists? Where are they this afternoon? So far the discussion has centered on trout culture.

MR. O. R. KINGSBURY (New York): In New York State this past year we collected carp from Oneida lake, fourteen tons of it, and put it in cold storage. We got herring from the Hudson river and put it in cold storage to feed trout. So far as bass propagation is concerned, it is the same with us as with everyone else, I believe—no one is sure just what the effect of feeding fish alone is. Some say it is not advisable to put fish on a straight fish diet, and we do not like to cut down our costs and produce disease among our fish by using plain fish as food. We use it simply to supplement other foods.

DR. WIEBE: For the past few years we have been feeding fresh ground carp exclusively to largemouth black bass. In two ponds last summer we raised four thousand bass averaging just about an ounce per fin, practically twenty thousand fish to the acre, which is pretty fair. They were fed exclusively on fresh ground carp, and they took it very readily.

Last summer we were experimenting with a pond of catfish—and in the southwest the catfish is a respectable fish, I may say for the information of anglers; in fact in many cases here they call it the channel catfish trout; they want to get the word "trout" in somewhere. We fed one group of fish exclusively on dried beef scraps and another group with fresh beef scraps, and the fish fed on fresh beef scraps were far superior to those fed on the dried beef scraps exclusively. My idea would be that the proper solution is a mixture of the two. For that reason we are conducting a series of experiments this season on varying preparations of dried beef scraps and fresh beef scraps, and also trying out salmon egg meal, salmon meal and liver meal. It is apparent it would be possible to cut down the proportion of fresh meat quite considerably and still get satisfactory results. Of course dried beef scraps cost only about $2.30 a hundred, whereas fresh beef costs from ten to twelve and in some cases seventeen cents a pound.

MR. FIEDLER: I think we should find out why we have to feed fresh meat products; if we did that we might be able to substitute something at a much lower price for that which we are now using.

MR. THADDEUS SURBER (Minnesota): I do not want to get into what threatens to be a controversy, but our experience in Minnesota in the feeding of frozen products to trout was a disastrous one. For the last three years I have not permitted the use of a pound of frozen beef hearts or beef livers, which is our principal food, as you no doubt know, because at our largest hatchery we lost practically all our brook trout by feeding frozen food; the loss was directly traceable to the use of frozen beef liver.

APPENDIX

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AMERICAN FISHERIES SOCIETY

Organized 1870

CERTIFICATE OF INCORPORATION

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certify in writing:

1. That the name of the Society is the American Fisheries Society.
2. That the term for which it is organized is nine hundred and ninety-nine years.
3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.

(b) To hold meetings.

(c) To publish and distribute documents.

(d) To conduct lectures.

(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.

(f) To acquire and maintain a library.

(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

SEYMOUR BOWER	(Seal)
THEODORE GILL	(Seal)
WILLIAM E. MEEHAN	(Seal)
THEODORE S. PALMER	(Seal)
BERTRAND H. ROBERTS	(Seal)
HUGH M. SMITH	(Seal)
RICHARD SYLVESTER	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

OF THE

AMERICAN FISHERIES SOCIETY

(As amended Sept. 11, 1935)

ARTICLE I

Name and Object

The name of this Society shall be American Fisheries Society.

The objects of this Society shall be to promote the cause of fish culture and its allied interests; to gather and diffuse information on all questions pertaining to fish culture, fish, and fisheries; and to unite and encourage those interested in fish culture, and fisheries problems.

ARTICLE II

Membership

The membership of this Society shall be classified as follows: Active, Club, Libraries, State, Patron, Honorary, and Corresponding.

Active Members.—Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society. The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. Any active member may, upon the payment of fifty ($50.00) dollars become exempt from the payment of annual dues though retaining the privileges of active membership for the duration of his life.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries.—Libraries may be admitted to membership upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for libraries shall be two ($2.00) dollars per year.

State Memberships.—Any state, provincial or federal department of the United States, Canada or Mexico may become a state member of this Society upon a two-thirds vote of the members present at any regular meeting and the payment of one year's dues. The annual dues for State memberships shall be ten ($10.00) dollars per year.

Patrons.—Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become a patron, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member of this Society upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President of the United States, the Governors of the several states, and the Secretary of Commerce of the United States, the Governor-General of Canada, the Lieutenant-

Governors of the several Canadian provinces, and the Dominion Minister in Charge of Game and Fisheries shall be honorary members of this Society while occupying their respective official positions.

Election of Members between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized to act upon all applications for memberships received while the Society is not in session.

Rights and Duties of Members.—Active members in good standing only shall have the right to vote at regular or special meetings of the Society. Any member is held to be in good standing whose dues are not more than one year past due. In case of non-payment of dues for one year, proper notice shall be given the member by the Treasurer in writing, and if such member remains delinquent one month from the date of such notices, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of one year, except upon payment of arrears and current dues. Each member of the Society in good standing, except honorary members, shall receive one copy of the annual volume of Transactions.

Quorum.—Twenty-five voting members shall constitute a quorum for the transaction of business.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, state members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund.—The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a president, a first vice-president, and a second vice-president, all of whom shall be elected for the term of one year and shall be ineligible for reelection to the same office until a year after the expiration of their terms; a secretary, a treasurer, a librarian, and five vice-presidents, one to be in charge of each of the following divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.
4. Angling.
5. Protection and Legislation.

The officers specified above, and the president of the previous year, shall form

an Executive Committee* with authority to decide the policies of the Society and to transact such business of the Society as may be found necessary, seven to constitute a quorum.

Only members in good standing who are in attendance or have been in attendance at one of the two immediately preceding meetings shall be eligible for election to the offices listed above and for appointment to any committee.

The officers shall be elected by a majority vote at a regular meeting, a quorum being present.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the regular and all special meetings of the Society and shall be ex-officio chairman of the Executive Committee.

The first Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, conduct its correspondence, promote its membership, and arrange for regular and special meetings. The Secretary shall also attend to the publication and distribution of the annual issuance of Transactions.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of seven thousand, five hundred ($7,500) dollars to be approved by the Executive Committee and to be paid for by the Society. The offices of Secretary and Treasurer may be occupied by the same person.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions.

The Vice-President of each division shall become conversant with the subject of his division and present a report on it at the regular meeting placing emphasis upon developments during the past year.

Committee members shall cooperate in performing the functions of their appointments and render reports as directed by the President.

ARTICLE V

Standing Committees

The standing committees shall be Executive; Foreign Relations; Common and Scientific Names of Fishes; and Publications. The Committee on Publications shall be appointed by the President. The Executive Committee shall be selected as provided for by article IV.

The Committee on Foreign Relations shall be composed of seven members selected for election by the nominating committee, and its duties shall be to exchange ideas pertaining to the various phases of fisheries administration, biology, including fish culture, with foreign fisheries biologists, conservation and fisheries administration officials, fish culturists or aquicultural societies. A report based on such exchange should be presented at each regular meeting.

* The Council was discontinued and the Executive Committee enlarged by amendment to By-laws September 11, 1935.

The Committee on Common and Scientific Names for Fishes shall be composed of seven members selected for election by the nominating committee. Its duties shall be to establish and maintain in the files of the Librarian of this Society a correct check list of the species of fishes occurring in the waters of the United States and Canada. This list should contain both scientific and common names.

The Committee on Publications shall be composed of five members, and its duties shall be to select and edit manuscripts submitted for publication. Papers shall be submitted ready for publication within thirty days after the close of the regular meeting. Such papers, together with the minutes of the regular and special meetings and the reports of the various divisions and committees, shall be published in an annual volume which shall be numbered in series with previous volumes and entitled: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY.

ARTICLE VI

Meetings

The regular meeting of the Society shall be held once a year, the time and place to be decided upon at the preceding meeting, or, in default of such action, by the Executive Committee. Special meetings shall be called by the President upon approval of a majority of the Executive Committee.

ARTICLE VII

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Application for memberships.
4. Reports of officers:
   a. President
   b. Secretary
   c. Treasurer
   d. Vice-Presidents of Divisions
   e. Standing Committees
   f. Special Committees
5. Committees appointed by the President:
   a. Committee of five on nomination of officers and standing committees for the ensuing year.
   b. Committee of five on time and place of next meeting.
   c. Committee of five on resolutions.
   d. Auditing committee of three.
   e. Committee of three on program.
   f. Committee of three on publicity.
   g. Committee of five on publications.
6. Reading of papers and discussions of same. In the reading of papers preference shall be given to the members present.
7. Miscellaneous business.
8. Adjournment.

ARTICLE VIII

Changing By-Laws

The By-Laws of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least twenty-five members are present at said regular meeting.

AMERICAN FISHERIES SOCIETY

LIST OF MEMBERS

(Showing Year of Election to Membership)

HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
Governor-General of Canada.
Lieutenant-Governors of the several Canadian Provinces.
Dominion Minister in Charge of Game and Fisheries.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'93 Borodin, Nicolas, Museum of Comparative Zoology, Harvard University, Cambridge, Mass.
'04 Denbigh, Lord, London, England.
'04 Kishinouye, Dr. K., Imperial University, Tokyo, Japan.
'17 Mercier, Honoré, Minister of Lands and Forests, Quebec, Canada.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15, Allen, Henry F. (Agent Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.
'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 Bond and Goodwin, 485 California St., San Francisco, Calif
'15 California Barrell Co., 22d and Illinois Sts., San Francisco, Calif
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore and Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503-4 Folsom St., San Francisco, Calif.

'15 Coffin-Redington Co., 35-45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co., C. W. Weld, Mgr., 301 Brannon St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3rd St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The. W. A. Barbour, Mgr. 443 Mission St., San Francisco, Calif.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware and Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Pope and Talbot, Foot of 3rd St., San Francisco, Calif.
'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Ray, W. S., Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609-11 Market St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California, James B. Brady, Gen. Mgr., 2nd and Folsom Sts., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.
'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

LIFE MEMBERS

'12 Barnes, Ernest, Fisheries Experiment Station, Wickford, R. I.
'00 Beeman, Henry W., New Preston, Conn.
'13 Belding, Dr. David L., 80 East Concord St., Boston, Mass.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'97 Birge, Dr. E. A., University of Wisconsin, Madison, Wisconsin.
'25 Bradford, W. A., 14 Wall St., New York, N. Y.
'04 Buller, A. G., Pennsylvania Fish Commission, Corry, Pa.
'12 Buller, Nathan R., Pennsylvania Fish Commission, Harrisburg, Pa.
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